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AUSTRALIAN SKY & TELESCOPE

THE ESSENTIAL MAGAZINE OF ASTRONOMY

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ON THE COVER

Astronomers are baffled by the behaviour of the massive black hole that lives at the centre of our Milky Way galaxy. See page 16.

Galactic mysteries

How is it possible to lose an entire galaxy? It sounds crazy, but it's not as uncommon as you might think, as our feature 'The case of the missing M102' describes (page 24). In these days of CCD cameras, dedicated professional survey telescopes and foolproof software applications, it's sometimes easy to lose sight (no pun intended) of the task that confronted earlier astronomers — particularly those of pre-photographic days — who had to make all their observations by eye and record them with pencil and paper. It would have been very easy to make the odd mistake here and there — accidentally missing an object, or counting the same one twice — and we should all have the utmost respect for the work they did. As we should for those intrepid folks such as author Michael Covington, who have been on the hunt for the answer to the true identity of M102. It's a fascinating tale..

The current generation of astronomers are performing galactic studies that would have been unimaginable to those earlier stargazers. I'm speaking in particular of the astrophysicists who are keeping an eye on the strange goings on in the centre of our own galaxy ('Into the heart of the Milky Way', page 16). It's long been known that a large black hole resides there (as indeed, probably occurs at the core of every sizeable galaxy). But that black hole seems to be very quiet – it's not an attention-seeker, as others tend to be. Yet its proximity makes it an ideal target for physicists and cosmologists who are trying to learn more about the nature of these enigmatic celestial beasts. The Milky Way's black hole and its immediate region remains a focus of intense study... and new observing projects promise to reveal more and more of its secrets.

If you want to see some exceptional galaxies for yourself, then our feature 'Monsters in the dark' (page 60) is just for you. So grab your telescope and start your galactic adventure!

Jonathan Nally
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AUSTRALIAN SKY & TELESCOPE

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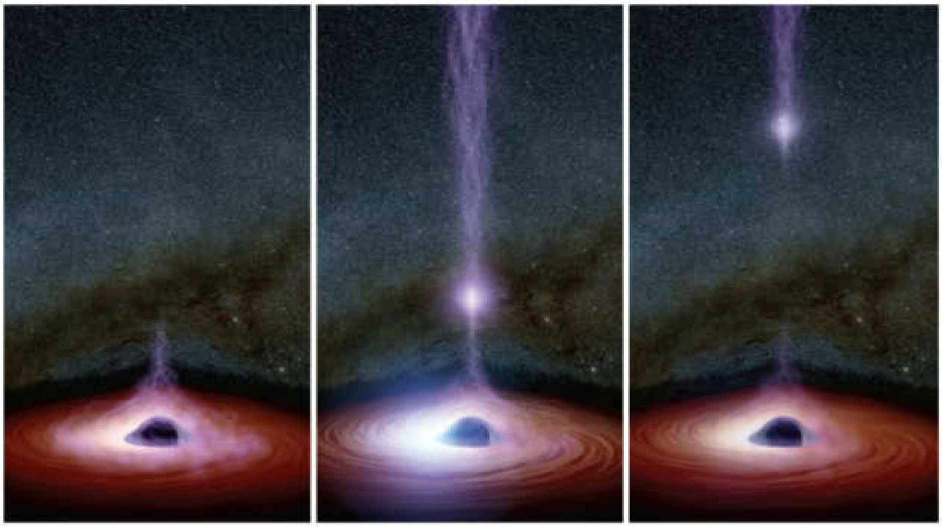
How black hole flares happen


NASA / JPL-CALTECH

This series of artist's illustrations shows what might happen when a supermassive black hole flares. The purplish glow around the black hole represents the corona, a haze of energetic particles that generate X-ray light. During a flare, the corona contracts *(left)*, then launches *(middle and right)*, beaming X-rays at observers in the direction of its motion.

Astronomers regularly watch black holes flare, but they're not actually sure why flares happen. New X-ray observations now suggest that the brilliant surges occur when a black hole's atmosphere contracts and launches away from it.

This atmosphere, called the corona, is a haze of high-energy electrons that hovers over the black hole and its accretion disk. Photons from the disk collide with the electrons and receive a mighty energy boost, becoming the X-rays we observe.

Dan Wilkins (Saint Mary's University, Canada) and colleagues used the Swift and NuSTAR space telescopes to watch how X-ray emission changed during a month-long flare from the active supermassive black hole in the galaxy Markarian 335, which lies roughly 300 million light-years away in the constellation Pegasus. They noticed that, even though the corona was bright and compact during the flare, the disk reflected fewer than half of the X-rays expected. The corona was still producing X-rays, yet most of them weren't hitting the disk.

The team thinks that, before a flare, the corona is spread out across the disk's surface. Then it gathers itself together into a vertical, jetlike structure, like a cat preparing to spring. This compact haze then launches off the disk at relativistic speeds. When an object moves that fast, it beams more of its radiation in the direction it's moving — which, in this case, is away from the disk. This effect is called *relativistic beaming*. Also, with the corona now farther from the black hole, more of the photons can escape the hole's gravity and reach us. These effects produce the apparent flare.

The flare ends when the jetlike corona collapses back to the disk. However, astronomers don't know why the corona launches in the first place. The study appears in the *Monthly Notices of the Royal Astronomical Society*.

■ **CAMILLE M. CARLISLE**

Magnetic fields weaken stars' inner sloshing

Astronomers have found an indirect way to discern the strength of magnetic fields within red giant stars.

Stars are roiling balls of plasma, and as they roil, their flickers and pulsations reveal clues to what's going on inside. Jim Fuller (Caltech) and colleagues used these changes to study a few dozen red giant stars that had been monitored for years by the Kepler spacecraft.

Red giants have finished fusing their core hydrogen into helium. They often exhibit half-and-half behaviour: first one hemisphere brightens, then it dims as the other lights up. This half-on, half-off pattern can be chalked up to sound waves sloshing through the star's interior. But the fluctuations seen in these few dozen red giants are weaker than those in hundreds of others that Kepler observed during the same time period.

To explain this weird behaviour, Fuller and colleagues propose that a super-strong inner magnetic field is weakening the brightness variations. In a red giant star, a large convective envelope of plasma surrounds a radiative core where fusion happens. Sound waves churn the outer envelope, interacting with ocean wave–like motions called *gravity waves* within the star's hot, dense plasma core. Sound waves can 'talk' to the gravity waves, donating energy to the core. But in the presence of a strong magnetic field, the gravity waves can't 'reply' — they're trapped in the core. So the sound waves' energy bleeds into the gravity waves, which themselves gradually dissipate. The lost energy has little effect on the giant star other than the slight weakening of the hemisphere brightness variations.

To explain the observations, a field of at least 100,000 gauss (10 teslas) must be lurking in these stars' cores. That's 100,000 times stronger than the Sun's polar magnetic field and 30 times greater even than sunspots, the strongest magnetic concentrations found on the Sun. The team published the results in the journal *Science*.

■ **MONICA YOUNG**

Around 360 million years ago, galaxy NGC 5291 (yellowish, just above left of centre) collided with another galaxy. The crash ejected a huge amount of matter into deep space, which eventually coalesced into star-forming regions and dwarf galaxies — pale blue and white areas stretching to the right-hand edge of the page. The densest part is dwarf galaxy NGC 5291N.
ESO

Have cryogenic volcanoes been found on Pluto?

Results from New Horizons' July 14, 2015, flyby of Pluto and its moons continue to trickle back to Earth, and in November at the American Astronomical Society's Division for Planetary Sciences annual meeting, mission scientists recapped details from the first 20% received.

The spacecraft's images have already shown that Pluto has an unexpectedly dynamic geology, with towering ice mountains, fresh plains of nitrogen ice that have slowly oozed like glaciers, and a deeply fractured crust. Now you can add 'giant ice volcanoes' to that list.

According to Oliver White (NASA Ames Research Center), the spacecraft imaged two broad, tall mountains that are perhaps 150 kilometres across and topped with depressions at their summits. They're dead ringers for the kind of broad shield volcanoes found on Earth (think Mauna Kea) and other inner planets — and very unlike anything ever seen on dozens of icy moons in the outer Solar System. "Whatever they are, they're definitely weird," admits White, "and 'volcanoes' is the least weird explanation at the moment."

The two mounds aren't immediately obvious in any given image, but they show up in the 3D topographic maps created by viewing the surface from multiple angles. The taller one, informally named Piccard Mons, is 5 kilometres high (16,000 feet); Wright Mons is 3 kilometres high.

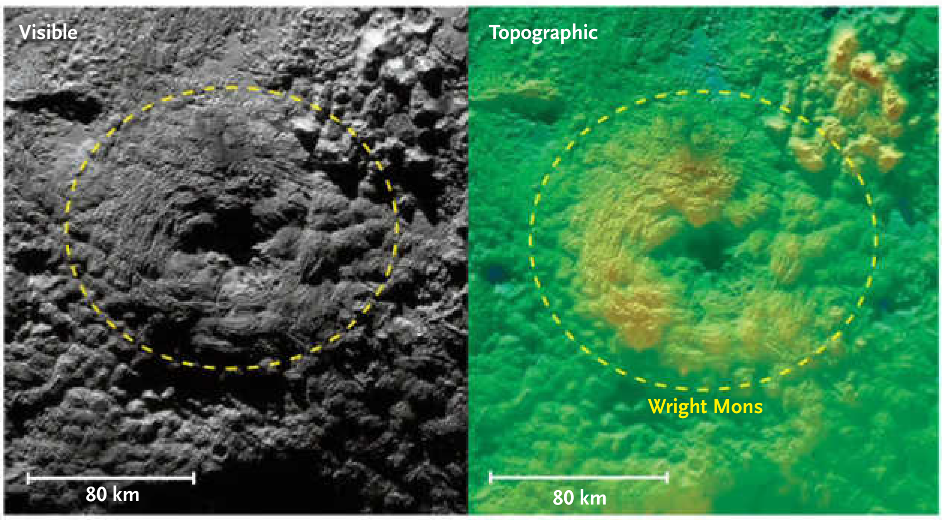
The 'lava' in this case was not molten rock — Pluto's interior is far too cold for that. Instead, it would have been a slushy mixture of water mixed with ammonia and other normally icy compounds that became liquefied deep down and gushed out onto the surface.

If these really are cryovolcanoes, their summit depressions formed when the source feeding them shut down and the peaks collapsed. Hummocky textures on their flanks might represent individual flows, though no one has yet offered details on their composition or origin.

Add 'Piccard' and 'Wright' to the growing evidence that Pluto's interior remained warm — and likely still *is* warm — for more than 4 billion years. Ordinarily, objects of this size should have frozen solid long ago. The interior heat isn't from tidal stretching and squeezing incited by another body, as occurs on Io thanks to Jupiter: Pluto and its big moon Charon are locked in a spin-orbit coupling that rules out tidal torquing. The only other plausible heat source would be the long-term decay of radioactive isotopes in the rocky core, which occupies most of Pluto's mass and about 70% of its diameter.

■ **J. KELLY BEATTY**

The informally named feature Wright Mons (centre feature) is about 160 kilometres wide and 3 kilometres (10,000 feet) high. Its summit depression is 56 kilometres across, and its sides exhibit a distinctive hummocky texture. Its shape matches that of shield volcanoes on Earth.



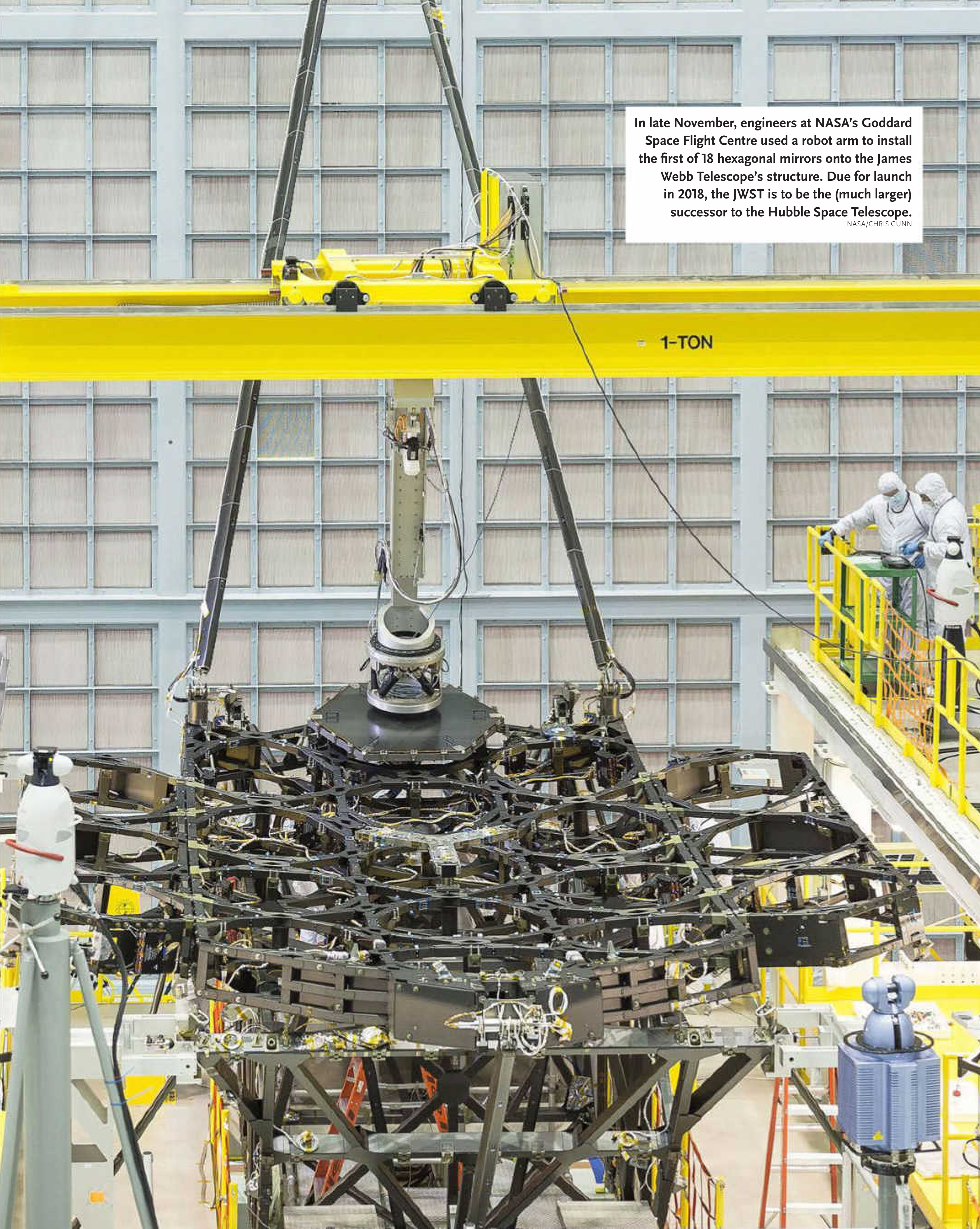
NASA / JHU-APL / SWRI (2)

IN BRIEF

Cracks on phobos. The enigmatic grooves on Mars' larger satellite were long thought to be a consequence of the formation of Stickney, a 9-km-wide crater that's a third of Phobos's length. But a new analysis by Terry Hurford (NASA Goddard) and others shows that many of the cracks align well with predicted tidal stresses induced by Mars. Phobos is slowly spiraling toward the Red Planet, and tidal forces can produce more than enough stress to fracture the surface. Although no new fractures have appeared in the decades since spacecraft first imaged Phobos at close range, some grooves are younger than others — as would occur if the process that creates them is ongoing.
■ **J. KELLY BEATTY**

Defining planets redux? Many astronomers have issues with the divisive, Pluto-demoting definition for a planet adopted by the International Astronomical Union in 2006. Strictly, it doesn't apply to exoplanets, nor does it define the upper mass limit for planethood. In a treatise to appear in *Astronomical Journal*, dynamicist Jean-Luc Margot (University of California, Los Angeles) suggests a relatively simple 'planet test' that depends only on the candidate's mass, orbital period and the mass of its host star. The upshot is that a body massive enough to clear its orbit of smaller interlopers within the star's lifetime is a planet. (Pluto would still fall short.)
■ **J. KELLY BEATTY**

Chance collision? Astronomers have recorded what looks like the aftermath of an impact on the asteroid 493 Griseldis. Images taken in March 2015 show a faint fan of dust coming from the asteroid, but the plume is absent from images taken the following spring and in 2010 and 2012. The feature's orientation is inconsistent with a cometary tail, and at the time Griseldis was far from the perihelion of its 5½-year orbit. So David Tholen (University of Hawaii) and colleagues think they have evidence of a substantial impact on the 46-km-wide asteroid's surface.
■ **J. KELLY BEATTY**



In late November, engineers at NASA's Goddard Space Flight Centre used a robot arm to install the first of 18 hexagonal mirrors onto the James Webb Telescope's structure. Due for launch in 2018, the JWST is to be the (much larger) successor to the Hubble Space Telescope.
NASA/CHRIS GUNN

Dusty mystery of the star AU Microscopii

Astronomers have discovered inexplicable ripples racing outward in a dusty disk that surrounds the star AU Microscopii. Gaps, clumps or warped features in such disks can signal the presence of forming planets. As part of an effort to look for these telltale signs, Anthony Boccaletti (Paris Observatory) and his colleagues imaged AU Mic with Sphere, an adaptive optics and coronagraph instrument at the Very Large Telescope in Chile.

But what they found was something utterly unexpected: wave-like arches on one side of the disk. Data gathered by the Hubble Space Telescope in 2010 and 2011 show the features, too. Between the four years spanned by the Hubble and VLT observations, the arching waves had moved at a breakneck pace through the disk, moving away from the central star at 4 to 10 kilometres per second.

Near-infrared images reveal at least five bright smears within the rippling disk, spaced 10 to 60 astronomical units from the star. They're probably dense clouds of dust. At least three are moving so fast through the outer disk (where, oddly, the waves move faster) that they could easily slip beyond the star's gravitational pull.

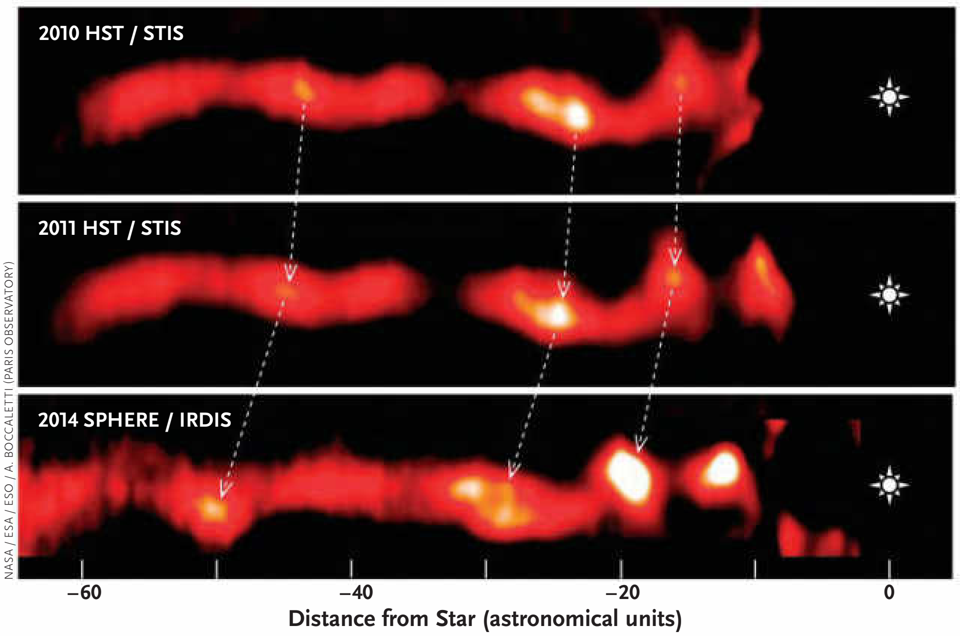
"This is a fascinating result," says Richard Nelson (Queen Mary University of London), who was not involved in the study. "But interpreting the observations is a real puzzle."

As the team reports in the journal *Nature*, such high speeds rule out any classic scenarios caused by orbiting planets. A warp carved in the disk by a nearby planet, for example, would move at comparatively lethargic speeds. Besides, Boccaletti's team searched carefully for a planet, with no luck. "If there was a planet in there and it was larger than six Jupiter masses, we'd be able to find it," says coauthor Dean Hines (Space Telescope Science Institute). "If there's something in there stirring up the pot, which there almost certainly is, it's going to be smaller than that."

The most promising scenario requires a violent interaction. Young stars like AU Mic can be very active, emitting giant flares that can wreak havoc on a surrounding planetary disk. A flare that hits a forming planet could easily strip material away and carry it outward at rapid speeds. Nelson, however, doubts whether even these speeds would be fast enough to match those found within the observed disk.

■ **SHANNON HALL**

Warps and bright features have travelled surprisingly fast through part of the disk surrounding the young star AU Microscopii. These images track the disk's changes over four years.



IN BRIEF

Closest star-shredding black hole. The observed last hurrah of a star wrenched apart by a supermassive black hole matches astronomers' predictions. In the journal *Nature*, Jon Miller (University of Michigan) and colleagues report the details of ASASSN-14li, the closest yet seen of these *tidal disruption events*. The event's light has a redshift of 0.02, so the photons travelled only about 290 million years to reach us. At this range, the astronomers can see spectroscopic signs of some sort of wind or filamentary debris moving toward us, but not fast enough to escape the black hole. It could be gas stuck along the (now disrupted) star's elliptical orbit, swinging out the farthest it can get from the hole. That would match computer simulations, which predict both that leftover gas will take a while to circularise its orbit.
■ **CAMILLE M. CARLISLE**

Small galaxies helped light universe. Hubble observations confirm that much of the ultraviolet light that broke up the early universe's hydrogen atoms came from the smallest galaxies. This breakup, called the *era of reionisation*, occurred within the universe's first billion years. Astronomers think that almost all of the ultraviolet radiation responsible came from star-forming galaxies, and simulations suggest that dwarf galaxies in particular might have contributed 30% of the ultraviolet energy needed. As part of the Frontier Fields project, Hakim Atek (Federal Polytechnic School of Lausanne, Switzerland) and colleagues went hunting for early, faint galaxies using the gravitational magnifying power of three massive galaxy clusters. They detected 252 galaxies from about 650 to 950 million years after the Big Bang and confirmed that such systems contributed about 20% to 60% of the needed ultraviolet photons. All told, there was enough radiation to totally reionise the universe by about 750 million years after the Big Bang, the team reports in an upcoming *Astrophysical Journal*.
■ **CAMILLE M. CARLISLE**

David Ellyard
Discoveries

A nod to James Bradley

The Astronomer Royal discovered an unexpected effect of the subtle pull of the Moon.

NASA/JIM GROSSMAN

Englishman James Bradley is one of the many astronomers whose achievements are little recalled nowadays. We've all heard about Copernicus, Kepler and Galileo, as well as the Herschels (father and son), and — nearer to our own time — Hubble. Edmund Halley, after whom a famous comet was named, was a man of many achievements, and they perhaps swamp our view of Bradley, whose protégé he was and who succeeded him as Astronomer Royal in 1742.

Yet Bradley has been credited with the two major astronomical discoveries of the 18th century. One provided the first solid proof that the Earth does actually orbit the Sun; the other gave evidence of the subtle influence of the Moon on the movement of the Earth. Both understandings were gained because Bradley was the supreme observer of his day — meticulous, patient, insightful, able to tease from the apparent motions of the stars in the night sky, clues to the workings of the cosmos.

Both discoveries came from the same source, the search for stellar parallax. If the Earth did orbit the Sun as Copernicus and Galileo had declared, and most astronomers accepted, then our point of view of the wider cosmos would be constantly shifting throughout the year, and the nearer stars would appear move back and forth by tiny amounts relative to those more distant. No one had yet seen such a movement, leaving open the possibility that the Earth did not move.

Bradley was in the hunt for parallax, along with many others. Over the course of years of observations, he found the stars did indeed appear to shift position throughout the year, but in a direction opposite to that expected from parallax and by a much larger amount. Bradley argued that this was the consequence of the movement of the Earth through space which minutely changed the direction on which light rays from the stars appeared to arrive, just as vertically-falling raindrops appear to move across the window of a moving car at an angle.

This phenomenon, which he called the aberration of light, enabled Bradley not only to claim that he had shown that the Earth moves, but also to give a more accurate figure for the speed of light. This made his reputation and helped to secure a big grant to buy new equipment at the Royal Observatory when he took over from Halley.

It was while he was in that post that he announced the second big discovery. A paper describing it was read in front of the Royal Society in February 14, 1747, which is why we recall it this month. Based on nearly 20 years of observation, Bradley declared that even when aberration was allowed, the stars he observed still had a tiny back and forward movement, again in the wrong direction expected from parallax.

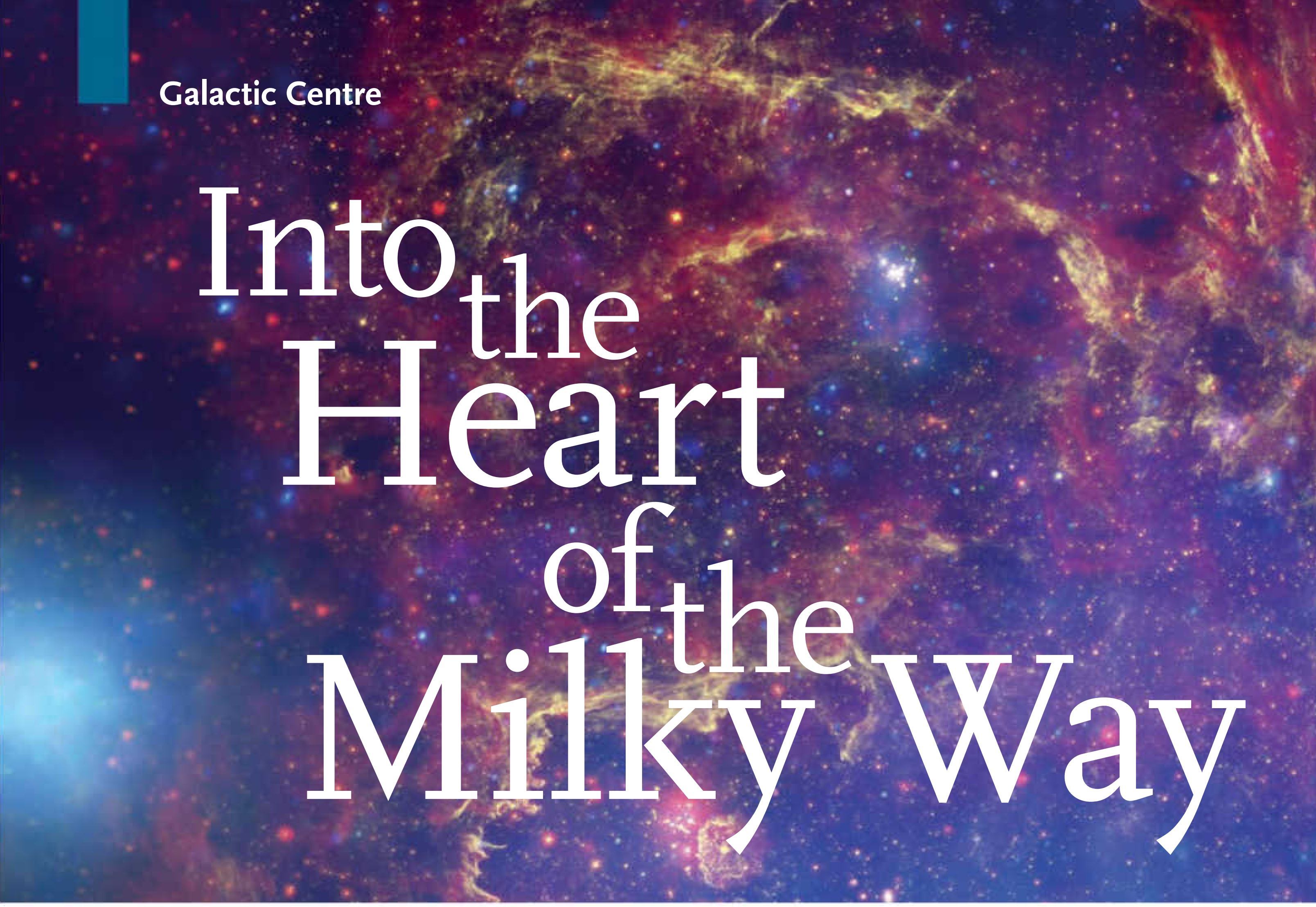
It was as if the axis of the Earth's rotation, which set the framework of imaginary grid lines in the sky against which the positions of stars was measured, was itself shifting regularly if subtly. This was an embellishment on the grand sweep known as precession, which sees the axis mark out a circle across the sky every 25,000 years. The newly found movement was like a series of scallops along the edge of that circle.

We already knew (thanks to Newton) that the gravitational pull of the Sun on the bulge at the Earth's equator drove precession. So Bradley argued that what he called nutation (after the Latin for 'nodding') was due to pull of the Moon. Such was his hypothesis but it could not be confirmed until the Moon had been through a cycle in its relationship to the Earth, which lasts nearly 19 years. Bradley's patience shines through in the fact that he waited and watched and measured for more than the required 19 years before announcing his finding... that the cycle of nutation and the cycle of the Moon's movement matched precisely.

The significance of all this? One lesson is the crucial importance of measurement, careful and painstaking and for as long as it takes. Another is that the movement of the Earth in space responds a combination of many extra-terrestrial forces. We are far from immune from the influence of the wider cosmos.

It took more nearly another century to finally detect stellar parallax, so small and subtle did it prove to be, and so to provide the irrefutable evidence that the Earth moves. While others completed the task, James Bradley had been in the vanguard.

***David Ellyard** presented SkyWatch on ABC TV. His StarWatch StarWheel has sold over 100,000 copies.*



Into the Heart of the Milky Way

When astronomers tuned in to watch our galaxy's supermassive black hole feed, they found more (and less) than they expected.

DARYL HAGGARD & GEOFFREY C. BOWER

The Milky Way Galaxy's nucleus is full of surprises. Scientists began to uncover exotic phenomena there more than 40 years ago, when they discovered the supermassive black hole, Sagittarius A* (Sgr A*, pronounced "saj A-star"), lurking at its core. Over the last several years, galactic-centre happenings have been particularly spectacular and unpredictable. In 2012, observers reported a small, dusty object nicknamed G2 plummeting toward the black hole. All eyes (and telescopes!) turned to watch this little daredevil's destruction.

Across the globe, astronomers followed G2's fall, monitoring it across the electromagnetic spectrum for many months, hoping to learn the object's structure and fate. But then, before our telescopic eyes, something completely unexpected appeared. In early 2013, several months before G2's closest approach to Sgr A*, astronomers caught a bright X-ray outburst. But it didn't come from the black hole. The combined X-ray powers of the Swift, NUSTAR, and Chandra observatories quickly revealed that this newcomer was a *magnetar*, a young, highly magnetic neutron star — the first of its kind to be seen in the galactic centre. Rapid radio follow-up conclusively placed this object at the distance of the galactic centre, very likely in orbit around the black hole (though at a larger distance than G2).

After all this action, Sgr A* would not be outdone. Later, in September 2013 and again in October 2014, Sgr A* shot off two of the brightest X-ray flares we've ever observed. Rich data from the G2- and magnetar-monitoring campaigns offered an unprecedented multiwavelength view of these bright flares. These observations may hold the keys to understanding the environment around our nearest supermassive black hole.

The G2 encounter

In 2012, a team of scientists led by Stefan Gillessen (Max Planck Institute for Extraterrestrial Physics, Germany) reported the discovery of G2, a faint infrared blob on a nearly suicidal slingshot orbit around Sgr A*.

In our galaxy's busy core, stellar nurseries live among aging and exploding stars and spinning stellar corpses. A supermassive black hole, Sgr A*, lurks in near (but not perfect) silence at the centre of it all.

NASA / JPL-CALTECH / ESA / CXC / STSCI

Already, astronomers could see that its path would take it within a couple hundred astronomical units (a.u., the distance between Earth and the Sun) of the black hole and deep into a hot, gas-filled environment.

Controversy ensued: was G2 a gas cloud, a gas-shrouded exoplanet, a star, or something altogether new?

Normally, Sgr A* is a notoriously quiet black hole, accreting only about a thousandth of an Earth mass every year. Early models for G2 estimated it to have about 3 Earths' worth of mass in gas. If a substantial fraction of this gas fell onto the black hole over the course of a few years, Sgr A* would morph into something akin to an active galactic nucleus (AGN), similar to those we observe in galaxies in the far reaches of the universe. To witness this transition would be spectacular.

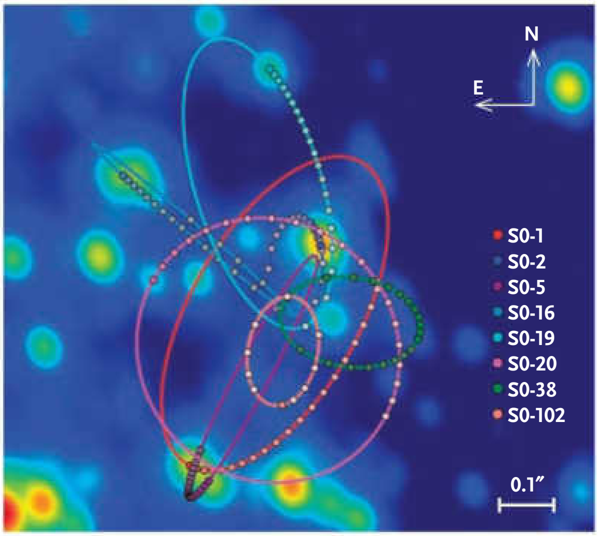
But G2 might not be wholly gas. Other interpretations yield equally compelling possibilities. G2 could be a gas-shrouded exoplanet torn from its parent star during a close encounter in one of Sgr A*'s stellar cohorts, tossed into a plunging, *Interstellar*-style orbit around the black hole.

Or perhaps it's a much more massive object: a star. If half the Sun's mass were buried inside G2's dusty, cool envelope, it could bind a puffy atmosphere and prevent it from being stripped as G2 passed near Sgr A*. But why the puffy shroud to begin with? One team, led by Andrea Ghez (University of California, Los Angeles), suggested that G2 could be the product of a

What is Sgr A*?

At a distance of 26,000 light-years from Earth, Sgr A* is the nearest supermassive black hole. Thanks to observations that monitor stars' orbits around this unseen dark object, we know its mass to excellent accuracy: between 3.8 and 4.8 million times the mass of the Sun.

Sgr A* feeds on winds blown out from massive stars in its vicinity. But for reasons we still don't understand, Sgr A* is an inefficient gas-guzzler. It swallows only a small fraction of an Earth mass per year (somewhere between 0.06 and 6 times the Moon's mass per year), blowing the rest back out into the galaxy. Its low-calorie diet leads to the surprising conclusion that the largest black hole in our galaxy is not a roaring lion but a cosmic pussycat, emitting about one-billionth of its maximum theoretical radiation.



UCLA GALACTIC CENTER GROUP / W.M. KECK OBSERVATORY LASER TEAM

CENTRAL STARS For about two decades, astronomers have used adaptive optics to monitor stars' orbital motions around the 4.3 million-solar-mass black hole sitting at the centre of our galaxy. Dots mark stars' average annual positions.

stellar merger. Perhaps two low-mass stars slammed into each other, robbed the stars of their angular momentum, and sent the merger product plunging toward Sgr A*. This collision would disrupt the outer layers of the two progenitor stars and, until they had a chance to settle, leave a merged star with an extended, cold, dusty veil.

From the infrared images taken in 2012, as well as archival images of G2 dating back to 2004, observers soon concluded that the object's strongest interaction with Sgr A* would occur in the autumn of 2014. Astronomers lined up to watch the encounter.

But despite continued infrared detections, radio, submillimetre, and X-ray observatories have come up dry so far. G2 didn't create the shock fronts we expected as it blasted through the hot gas around Sgr A*, nor has it yet bumped up Sgr A*'s accretion rate or created a jet.

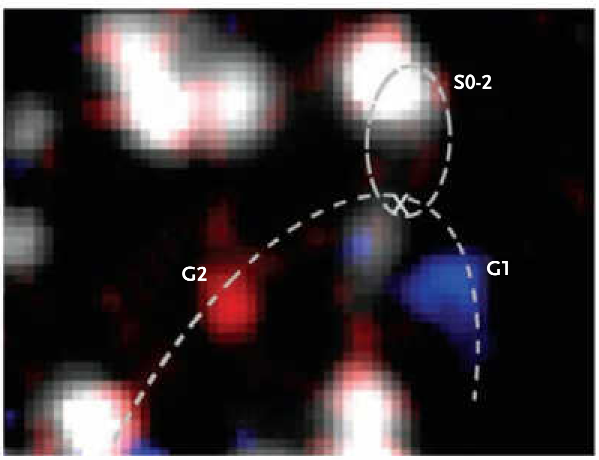
The lack of radio waves from a shock front means G2 is smaller than originally thought. Many think the size limits inferred from radio observations strengthen the stellar interpretation. The object could still be fairly big within those limits, similar in size to some of the largest known stars, so-called hypergiants, whose diameters can reach up to roughly 20 a.u.

But the cloud idea isn't ruled out yet. It's just that if the object were a cloud, some force would need to act on it to limit its size. A strong magnetic field could deform the cloud, stellar winds might confine it, or we might be seeing the gaseous veil surrounding a merged star. The case remains wide open.

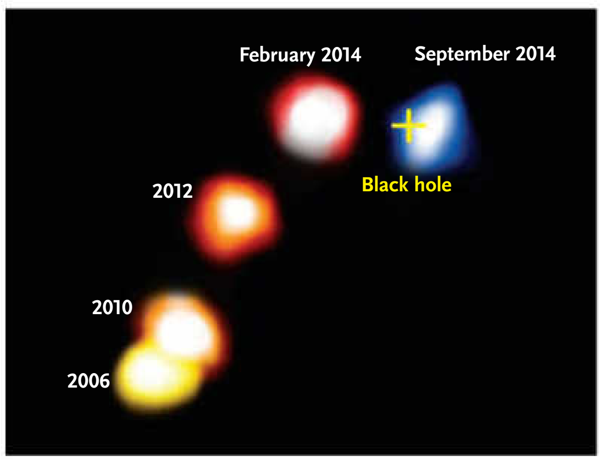
At the moment, observers are watching G2 as it re-emerges from behind Sgr A*. Ghez's team, using infrared images from the Keck telescopes, has seen the object reappear intact, which they say supports the star scenario. However, spectroscopic data collected from Gillessen's team suggest that the gas tail was significantly disrupted during the close encounter, which is evidence of tidal streams shorn from a cloud. Hope remains that we could still see an increase in accretion onto Sgr A* on long time scales, perhaps spread over several years.

Due to the different nature of their data, the two teams might be looking at different sides of the same coin: even if the black hole yanked some gas off G2, there may yet be a star lurking within the gaseous envelope.

What of Sgr A* itself? Did the black hole notice all this action in its domain? In the midst of the G2 observing frenzy, Sgr A* offered up some surprises of its own.



O. PFUHL ET AL. / *ASTROPHYSICAL JOURNAL* 2015



ESO / A. ECKART

WATCHING G2 ***Left:*** **An archival image from 2006 reveals G2 (red), the dusty body discovered traversing the galaxy's centre in 2011. (A similar object named G1 is shown in blue.) Even with adaptive optics, the Very Large Telescope (VLT) in Chile sees stars as blobs of near-infrared light (white/gray). Dashed lines show the orbits of G2 and a close-in star named S0-2, which zips around Sgr A* every 16 years.** ***Right:*** **In this composite VLT image, colours indicate G2's velocity: the object receded from us as it approached the black hole (yellow, orange and red), now it's rounding the bend and coming back (blue). Both images are about 0.1 light-year across.**

Can a magnetar probe general relativity?

The discovery of a magnetar in the galactic centre has opened up an opportunity for studying stellar evolution in the galaxy's frenetic downtown, understanding black holes, and perhaps even testing Einstein's theory of general relativity. In fact, astronomers have long sought to discover a pulsar in orbit around Sgr A*, which could provide an unprecedented measurement of the black hole's mass and spin, as well as test for deviations from our current theory of gravity.

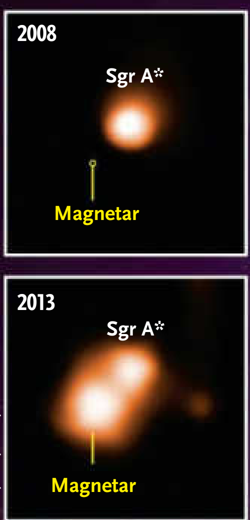
The power to make these exquisite measurements comes from the stability of these massive and energetically spinning objects. Pulsars are arguably the best-known clocks in the universe: a pulsar's period and its change over time are often measured to 10 significant digits, sufficient to track changes in the arrival time of individual pulses with accuracies better than 1 microsecond. So a pulsar orbiting a black hole is a relativist's dream — its pulses would trace the black hole's complex spacetime structure, and subtle but predictable changes in the pulses' arrival time would reveal the black hole's mass and spin.

The magnetar in the galactic centre is unfortunately too far away and too jittery to perform these kinds of measurements. At its distance, it will take at least 700 years to orbit Sgr A*. And due to instabilities arising from its strong magnetic field, a magnetar makes a poor clock — more like an old spring-wound wristwatch than a precision atomic timepiece.

Nevertheless, we plan to continue watching the magnetar over the coming years. With luck, it will remain bright enough to reveal whether its motion describes an orbit around Sgr A*.

Ordinary pulsars may not be found in orbit around Sgr A*. Fortunately, this is not the end of our quest to use pulsars to probe fundamental physics around Sgr A*. Millisecond pulsars, which spin so fast they're close to breaking apart, are old neutron stars that have 'spun up' by interacting with a companion star.

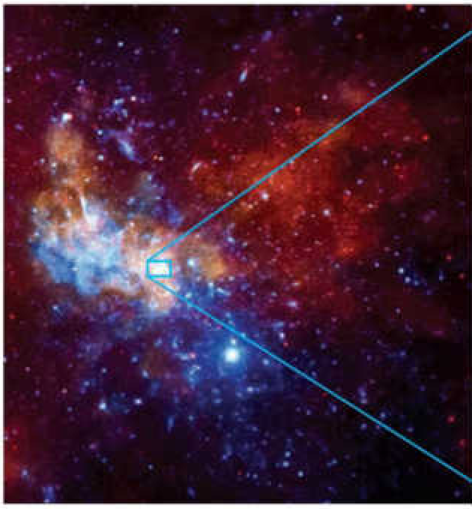
Current radio telescopes would miss any millisecond pulsars in the galactic centre due to radio wave scattering. But a new generation of radio telescopes, including MeerKAT in South Africa and the Square Kilometre Array in South Africa and Australia, will have the sensitivity to detect these fast-spinning pulsars in Sgr A*'s vicinity and, if successful, help us test general relativity.



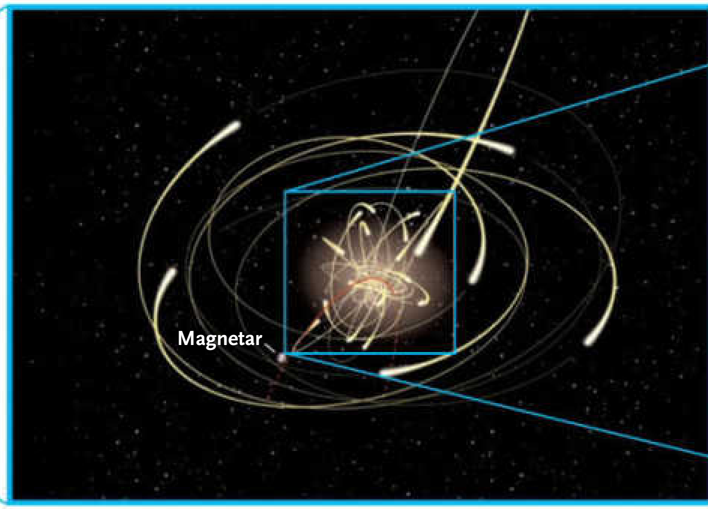
NASA / CXC / INAF / F. COTI ZELATI ET AL., *MNRAS*, 449, 2685, 2015

MAGNETAR A neutron star with extraordinarily powerful magnetic fields, SGR 1745-2900 lies as close as 0.3 light-year to Sgr A*. Chandra captured the magnetar's X-ray outburst in 2013 (*above*). An artist's conception (*right*) shows how an outburst might happen: a rupture in the neutron star's solid crust, accompanied by a rearrangement of the magnetic field, could release tremendous amounts of energy.

ART: NASA GSFC / S. WIESSINGER



INTO THE HEART This image from the Chandra space telescope captures X-rays from the busy galactic centre in a view 50 light-years across. Red, green and blue indicate low, medium and high-energy X-rays, respectively.



STELLAR DISK + MAGNETAR Drawing from near-infrared data gathered by the Keck telescopes, this frame shows stellar orbits in the galactic centre. Stars farther out tend to orbit clockwise in a disk, while the closer-in cluster contains stars on more chaotic orbits. The X-ray-emitting magnetar is a projected 0.3 light-year from the centre. G2's current orbit follows the red track.

Inflows, outflows and flares

X-ray observations confirm that Sgr A* feeds off stellar winds. But most of that mass never makes it all the way to the gaping maw. Daniel Wang (University of Massachusetts, Amherst) led a team that studied X-ray emission around Sgr A*. The researchers reported that less than 1% of the material flowing toward the black hole successfully makes the journey inside — the other 99% blows back out into the surrounding environment.

In the process, our delicately snacking black hole belches X-ray flares: mild bursts occur roughly once a day, and bright spikes appear every 10 days or so. Thanks to G2 monitoring in 2013 and 2014, one of us (Haggard) led a team that discovered two of the most impressive X-ray flares ever seen. Over the course of a couple of hours, each released several hundred times the X-rays normally seen from this region.

Simultaneous multiwavelength observations (when they exist) generally show infrared and radio-wave spikes accompanying X-ray flares. But the inverse isn't true — a typical day sees four times as many infrared flares as X-ray flares. So it's not clear how emissions at different wavelengths relate to each other.

Because of these uncertainties, we still don't understand the flares' origin. A reordering of magnetic fields could create flares in a way similar to those seen from our Sun. Or the black hole's extreme gravity might shred the occasional asteroid that comes in a little too close.

The X-rays brighten and fade within a couple of hours. If they arise in the accretion disk, then their source must lie just outside the black hole's event horizon, the point of no return for material and light entering the black hole. Since that puts the escaping X-rays within an a.u. from the black hole, in the thick of whatever gaseous flow feeds Sgr A*, the flares are unlikely to be connected to G2's closest approach at roughly 150 a.u.

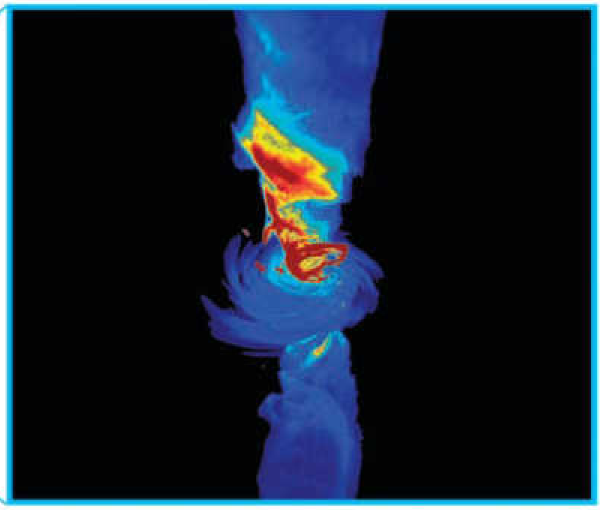
Nevertheless, a recent study of 150 Chandra and XMM-Newton observations spanning 15 years, led by Gabriele Ponti (Max Planck Institute for Extraterrestrial Physics, Germany), shows that bright flares became more frequent about six months after G2 made its closest approach to the black hole. Coincidence? Maybe — other black holes show similar flare clustering.

Continued multiwavelength monitoring of Sgr A* is our best hope of pinpointing the source of the flares.

Discovery of an exotic pulsar

The same monitoring that followed G2's approach and captured two brilliant flares led to another surprise on April 24, 2013. As G2 approached Sgr A*, daily monitoring of the black hole with the Swift satellite jolted scientists with the announcement of a bright X-ray outburst. Observers around the world rushed to their telescopes to capture a more complete picture of the anticipated disruption of the G2 cloud.

But the picture quickly became much more complex. The X-ray outburst lasted for hours, then days — much longer than the typical 1- or 2-hour duration of an X-ray flare from Sgr A*. Radio telescopes in the United States and Japan, on the other hand, didn't see the expected jump in radio emission, which typically follows Sgr A*'s bright X-ray flares. This was clearly not an ordinary enhancement of



SUPERMASSIVE BLACK HOLE This frame from a recent simulation shows radio emission from around Sgr A* as it accretes from a small gas flow and spews a jet. The view spans 6 astronomical units, a distance slightly larger than Jupiter's orbit around the Sun.

CLOSING IN ON G2 This frame, a few tenths of a light-year on a side, zooms in on the central cluster of stars, suffused by the gentle glow of hot, X-ray-emitting gas that's on its way toward the black hole. G2's observed orbit followed the red solid line; the dashed line extrapolates a bit beyond observations.

activity around the black hole.

Two days after the initial outburst, NASA's NUSTAR X-ray telescope discovered that the emission was not steady but in fact pulsed every 3.76 seconds. Radio telescopes in Australia, the United States and Germany confirmed radio pulsations with the same period shortly after that. Within five days of the initial outburst, the sharp eyes of the Chandra X-ray Observatory demonstrated that the pulsed emission arose not from Sgr A* but from a compact object only 3 arcseconds, or 0.3 light-year, away from the black hole.

This rapid response of space- and ground-based telescopes across the electromagnetic spectrum provided unambiguous evidence that this outburst came from an exotic compact object known as a *magnetar*.

When massive stars with less than 25 solar masses burn through all their nuclear fuel, they explode in a supernova, leaving behind a crushed object composed almost entirely of neutrons. This remnant packs one to two times the mass of the Sun into a sphere comparable in size to a small asteroid, only 10 kilometres in diameter. Moreover, the neutron star is born spinning as fast as 600 revolutions per second. If the jet of radiation spewed out of its magnetic poles sweeps across our line of sight, we call it a pulsar due to the jet's lighthouse effect.

Pulsars are exotic enough in their own right, but magnetars are stranger still. Possessing magnetic fields 100 times stronger than that of a typical pulsar, they're rare: astronomers have discovered thousands of pulsars in the galaxy, but only 30 or so magnetars. Where their strong fields come from isn't known, but the magnetic energy appears to drive magnetars' characteristic X-ray flashes. Dramatic rearrangement of the fields at the star's surface leads to explosive heating, creating a thermal hot spot that cools slowly over time.

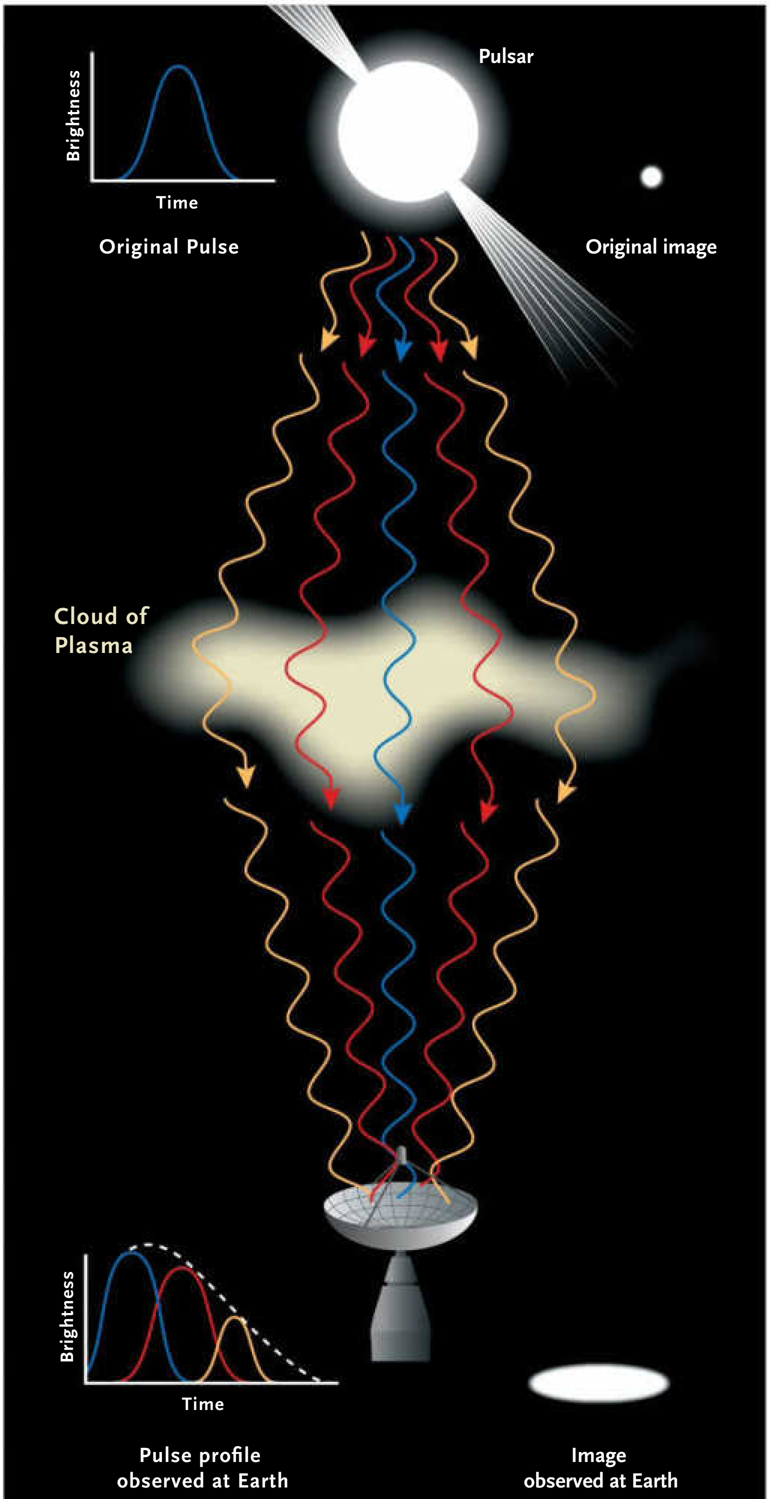
The galactic centre magnetar is still cooling off two years after its initial outburst, its X-rays steadily declining in intensity. Mysteriously, its radio emission, which radiates from charged particles racing around the pulsar's strong magnetic field, has remained steady.

The missing pulsar problem

The galactic centre is full of young, massive stars of exactly the type that one would expect to go through a supernova phase and result in a neutron star or black hole. Some of these stars have been used to study the gravitational field of Sgr A* as they orbit the black hole. Theorists have suggested that there might be thousands of pulsars close to Sgr A*, leading to

Sgr A* and friends

Galactic nucleus	Black hole mass (in solar masses)	Accretion rate (solar masses per year)
Sgr A* (quiet nucleus)	3.8 – 4.8 million	10^{-7} – 10^{-9}
M87 (active but low-luminosity nucleus)	3 – 6 billion	< 0.001
3C 273 (quasar, very active nucleus)	0.9 – 2.4 billion	4 – 10



PLASMA-SMEARED PULSE When a spinning neutron star emits an earthward pulse, some radio waves travel directly to us. But most of its photons encounter free electrons floating in clouds of plasma, which force radio waves on detours. By the time scattered photons converge on an earthbound detector, the pulsar's point-like image has smeared out. Moreover, the longer paths of scattered photons delay their arrival times, smudging the pulse profile in time as well.

S&T: GREGG DINDERMAN; SOURCE: G. BOWER

numerous searches at radio wavelengths.

But none of these searches has uncovered a pulsar any closer to the centre than about 80 light-years, a distance too far away for them to be gravitationally bound to Sgr A*. This absence of radio pulsars has proved puzzling and made the magnetar's discovery all the more surprising.

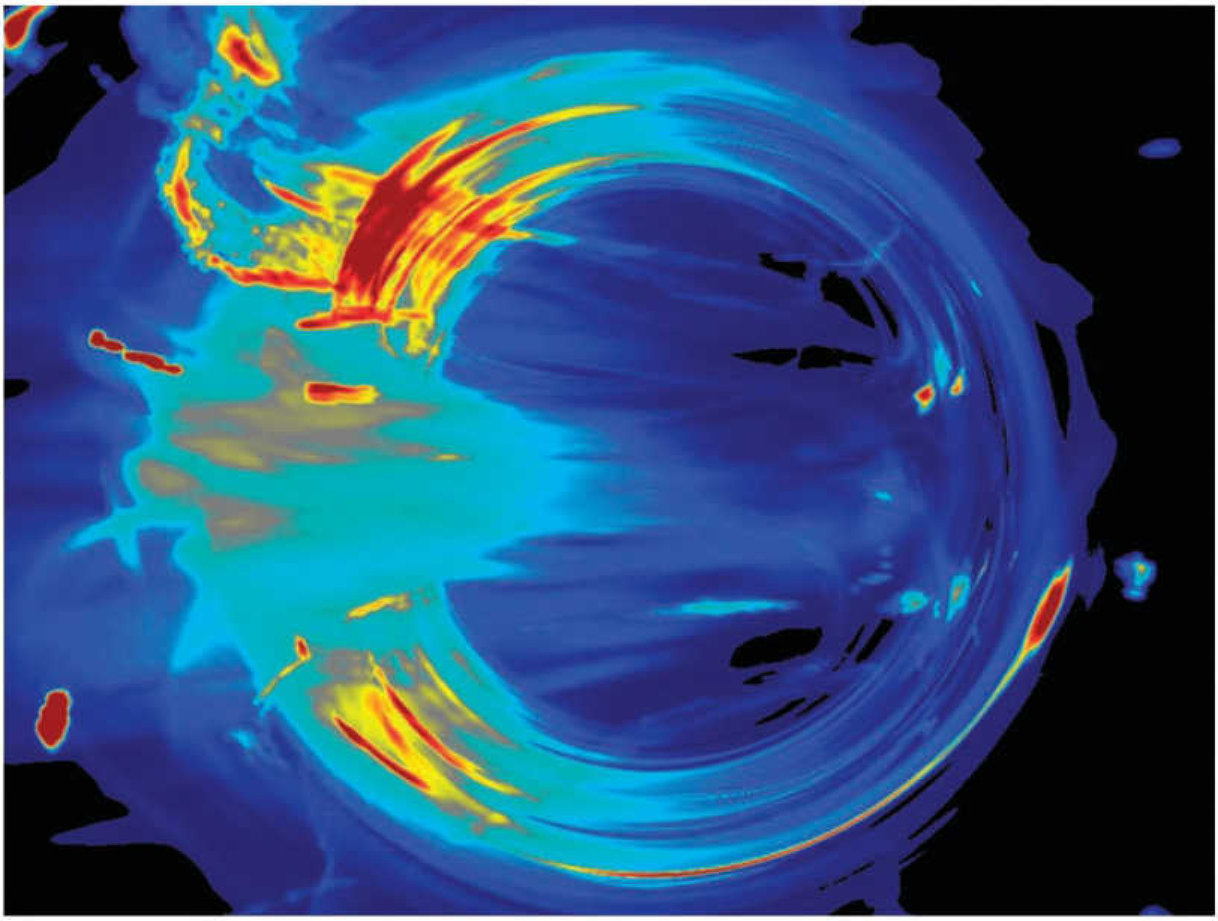
For the past two decades, the leading explanation has been not the absence of pulsars but the cloaking of their signal. Dust obscures the galactic centre at visible wavelengths even as radio waves pass right through. But plasma, ionised gas between Earth and the galactic centre, scatters radio waves and blurs images of radio sources such as Sgr A* (see box at left). The blurring has the effect of smearing individual pulses of radiation. If that smearing in time is longer than the pulse period of a particular pulsar, then the pulsar will cease to appear as a pulsed source and we won't detect it in our searches.

The smearing effect is strongest at long radio wavelengths and diminishes rapidly at shorter wavelengths. But perversely, typical pulsars become fainter at shorter wavelengths, making them much harder to detect.

One of us (Bower) used the Very Long Baseline Array, a transcontinental network of radio telescopes, to measure the effects of scattering on the radio waves coming from Sgr A* and the magnetar. We have long known that Sgr A* is one of the most heavily scattered objects in the galaxy, and new observations show that the magnetar suffers exactly the same fate, leading to a blurred image of the magnetar. This isn't surprising because the two objects are so close together.

But the second measurement, showing how much the magnetar's individual pulses smeared in time, was quite surprising. Current understanding suggested that pulses might smear by as much as 100 seconds at a wavelength of 30 cm, much longer than the typical pulsar period. But our observations showed that the magnetar's pulses are smudged by only 1 second at 30 cm, and even less at shorter wavelengths. If the 'missing' pulsars are in the galactic centre and behind the same amount of material, previous surveys should have easily seen through the fog of interstellar plasma to find them.

So why have past searches failed? And why was the first pulsar discovered in the galactic centre a rare magnetar? Perhaps these facts tell us that the extreme conditions in the galactic centre, such as strong magnetic fields and dense gas, drive the formation of stars and neutron stars that are more highly magnetised than their ordinary cousins throughout the Milky Way. Some have suggested far more exotic



M. MOSCIBRODZKA ET AL., A&A, 570, A7, 2014, REPRODUCED WITH PERMISSION © ESO

HUNGRY BLACK HOLE
This simulated radio image, about 1 a.u. across, gives an edge-on view of gas flowing around and into the black hole. The black hole's gravity bends radiation from this flow into an apparent ring-like structure.

ideas: neutron stars might accrete dark matter, which should be prevalent in the galactic centre, then implode into black holes. Or more prosaically, perhaps the scattering effects of the interstellar medium are more complex and time-variable than our current models can account for.

What's up next?

The galactic centre is often described as the kitchen sink of the galaxy: a medley of anything and everything in the cosmos. And it's clear that the banquet isn't over yet. A new suite of observatories, combined with recent happenings in the galactic centre, promise new discoveries and deeper understanding.

Among the most promising new tools available to astronomers is the project known as the Event Horizon Telescope. This network will bring together an array of powerful radio telescopes in California, Hawai'i, Arizona, Mexico, Chile, Spain, France, Greenland and Antarctica to image Sgr A* at millimetre wavelengths with an angular resolution comparable to the black hole's event horizon.

EHT images will reveal the inward accretion flow as well as the outflow (if there is one) on an unprecedented scale, potentially showing material that circles the black hole on the innermost stable orbit with a period of 20 minutes or less. When combined with X-ray studies of flares, we will be able to trace the flow of gas from the outer edge of the accretion flow all the way to the edge of the event horizon.

Even more importantly, the EHT will explore the structure of spacetime on those same scales, imaging the strong gravitational lensing effects that lead to a 'shadow' and ring of emission around the black hole. Short of the discovery of a pulsar in close orbit around Sgr A*, these observations will provide the most compelling test of general relativity and our best view ever of the supermassive black hole at the heart of the Milky Way. ✦

Daryl Haggard *is an assistant professor at McGill University, where she studies the interplay between supermassive black holes and their host galaxies.*
Geoffrey C. Bower *is an astronomer at the Academia Sinica Institute of Astronomy and Astrophysics, where he investigates transient radio sources, black holes, and instruments and techniques for radio astronomy.*

The case of the Missing M102

Did a false lead 232 years ago hide the truth about this 'nonexistent' galaxy?

MICHAEL A. COVINGTON

For more than two centuries astronomers have referred to about 100 prominent star clusters, nebulae and galaxies by numbers such as M31 and M42. These are from the Messier catalogue, published in instalments from 1771 to 1781 by the French comet-hunter Charles Messier. He was primarily documenting objects that could be mistaken for comets. Messier's own 13 comet discoveries have faded into history, but his list of non-comets was such a convenient tally of deep sky objects

PICK ONE Is the nonexistent 'M102' actually NGC 5866 (below) and not M101 (left) as long thought? In deep images at the same scale they appear utterly different, but their bright cores look similar through small scopes.

M101: MASIL IMAGING TEAM; NGC 5866: MICHAEL COVINGTON

for small telescopes that astronomers quickly adopted it and have used it ever since.

This part of the story is well known, but then the tale grows complex. Since Messier's time the catalogue has developed and matured, in several stages. It originally gave incorrect positions for some objects, and it failed to number the last few objects that Messier had noted. The catalogue took its more-or-less accepted present form in the mid-20th century, when astro-historians added M104 through M110 and addressed the questionable identities of M47, M48, M91 and M102.

Most US reference books treat M102 as a duplicate observation of the far northern galaxy M101, because M102's 'discoverer,' Messier's contemporary Pierre Méchain, later wrote that he had made this mistake. Many European observers, however, identify M102 with the smaller galaxy NGC 5866, and here I shall argue that they are probably right. My arguments parallel those of amateur astronomer Hartmut Frommert, who has analysed the situation in detail, but I can offer some simplification.

Mistaken identity

NGC 5866, as the Cambridge *Atlas of the Messier Objects* notes, is fainter than M101 (magnitude 9.9 vs. 7.7) but has a much greater average surface brightness (20.8 versus 23.7 magnitudes per square arcsecond). Both are visible through 10×50 binoculars under excellent conditions, and both are easier to see than some other Messier objects. Thus, both should have been within reach of Méchain's and Messier's modest instruments.

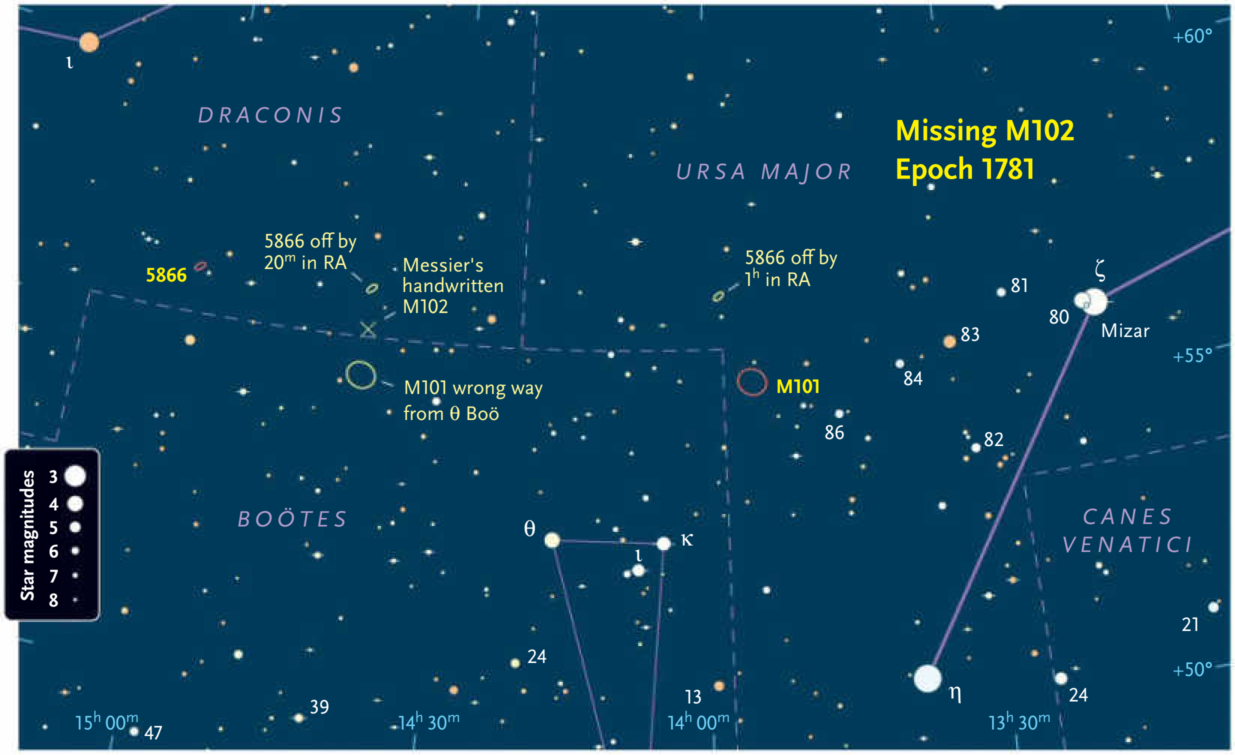
Through large telescopes or on long-exposure photographs they look quite different: M101 is a huge, nearby spiral seen face-on, and NGC 5866 is a more distant galaxy appearing edge-on. However, their bright innermost areas are all that show through a small scope, and can look similar as barely visible smudges. As amateur astronomer Richard Jakiel told me, NGC 5866 resembles the central part of M101 when a hazy sky or inadequate telescope hides the latter's big disk of spiral arms. My first casual attempt to see NGC 5866 was successful, with a 20-cm telescope, even though I was in town and the full Moon was in the sky. So I don't think it's too faint for Méchain to have seen and recorded.

Facing the facts

One must account for four facts: (1) Messier's description of M102; (2) an obvious typographical error in his description (the Greek letter omicron in place of theta); (3) Méchain's retraction, asserting that M102 was just M101; and (4) Messier's handwritten position for M102 in his personal copy of his catalogue.

By themselves, (1) and (2) point clearly to NGC 5866; (3) does not, but I shall argue that it should not be taken at face value; and (4) is a puzzle for either theory, to which I shall propose a simple solution.

Start with Fact (1). In the final instalment of his catalogue, published in the French astronomical almanac *Connoissance des Temps* for 1784 (issued in 1781), Messier adds, at the end of his list, three objects that his colleague Méchain had found. Messier gives coordinates for only one of them. Here are his descriptions, in the original French; my translations follow:



Par M. Méchain, que M. Messier n'a pas encore vue.
By Mr. Méchain, [objects] that Mr. Messier has not yet seen:

101.
R.A. 13h 43m 28s (208° 52′ 4″) ["208" should read "205"].
Declination 55° 24′ 25″.
Nébuleuse sans étoile, très-obscure & fort large, de 6 à 7 minutes de diamètre, entre la main gauche du Bouvier & la queue de la grande Ourse. On a peine à la distinguer en éclairant les fils.
Nebulosity without a star, very obscure and rather large, from 6 to 7 arcminutes in diameter, between the left hand of Boötes and the tail of Ursa Major. Difficult to distinguish when the micrometer wires are illuminated.

102.
[No R.A. or declination given.]
Nébuleuse entre les étoiles ο du Bouvier & ι du Dragon: elle est très-foible; près d'elle est une étoile de la sixième grandeur.
Nebulosity between the stars ο Boötis and ι Draconis: it is very faint; close to it is a sixth-magnitude star.

103.
[No R.A. or declination given.]
Amas d'étoiles entre ε & δ de la jambe de Cassiopée.
Cluster of stars between ε and δ of the leg of Cassiopeia.

Here M101 and M103 are easy enough to identify. But the description of M102 is problematic.

Fact (2) is that in Messier's description of M102, "ο" Boötis must be a misprint for "θ" Boötis. Historians agree on this, because nothing else makes sense. In order for M101 and M102 to be confusable they must be fairly close together. Omicron (ο) Boötis is far away from M101 and from the other reference star, Iota (ι) Draconis. Theta (θ) Boötis, on the other hand, is a near neighbour of Iota Draconis, and there is no Greek-lettered star between them. It would be natural to describe an object as 'between' Iota and Theta. It is not clear whether the misprint was on Messier's star chart or arose from a mistake by Messier or by the printers of the *Connoissance des Temps*.

Fact (3) is that, shortly after the catalogue was published, Méchain retracted his observation of M102, stating that it was an error: a duplicate observation of M101.

The *Berliner Astronomisches Jahrbuch* for 1786, issued in 1783, contains a letter from Méchain, printed in German, announcing additional discoveries and asserting that M102 was a mistake. About M102 Méchain says the following (as quoted by Helen Sawyer Hogg in a 1947 article in the *Journal of the Royal Astronomical Society of Canada*; my translation follows):

Seite 267 der Connoissance des tems f. 1784 zeigt Herr Messier unter No. 102 einen Nebelfleck an, den ich zwischen ο Bootes und ι Drachen entdeckt habe; dies ist aber ein Fehler. Dieser Nebelfleck ist mit dem vorhergehenden No. 101 ein und derselbe.

Herr Messier hat durch einen Fehler in den Himmelscharten veranlasst, denselben nach dem ihm mitgetheilten Verzeichnisse meiner Nebelsterne verwechselt.

On page 267 of the *Connoissance des tems* [an older spelling] for 1784, Mr. Messier shows under No. 102 a nebula that I am supposed to have discovered between ο Boötis and ι Draconis; however, this is an error. This nebula is one and the same with the preceding No. 101. Owing to an error in the star charts, Mr. Messier has confused it in the list of my nebulae that was shared with him.

Méchain sent a similar but shorter letter to Berlin's French-speaking Académie Royale des Sciences et Belles-Lettres, which the academy published in French. It, too, refers to "an error in the star charts" but lacks the final clause attributing the mistake to Messier. Frommert speculates that the German editor and translator, the eminent astronomer Johann Elert Bode, added that clause.

Either way, this retraction does not make clear what the error was supposed to have been. Maybe Méchain himself was not sure. It is interesting to note that neither the *Connoissance des Temps* nor any other major French outlet ever published Méchain's retraction. Perhaps Méchain lost confidence in its accuracy.

Fact (4) is that in his personal copy of the catalogue, Messier handwrote a rough position for M102, and it's not that of NGC 5866, M101 or any other galaxy or nebula. It is, according to Frommert, R.A. $14^h\ 40^m$, declination 56°. This point (in the coordinates for 1781) is plotted with an X on the chart on the previous page. Messier's handwritten position shows that, at that time

"The retraction does not make clear what the error was supposed to have been. Maybe Méchain himself was not sure."

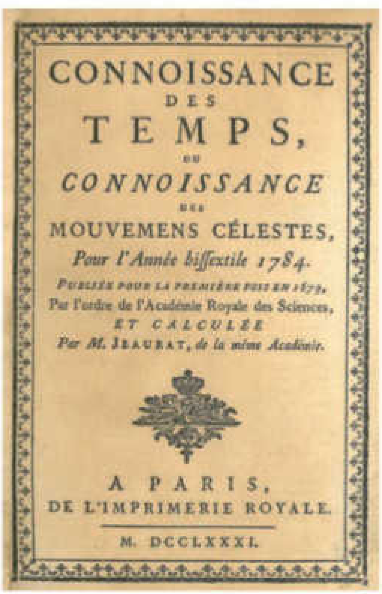
at least, he did not believe that M102 was a duplication of M101. But the position is imprecise; the declination is given only to the nearest degree, and the right ascension to the nearest 20 minutes.

A new view

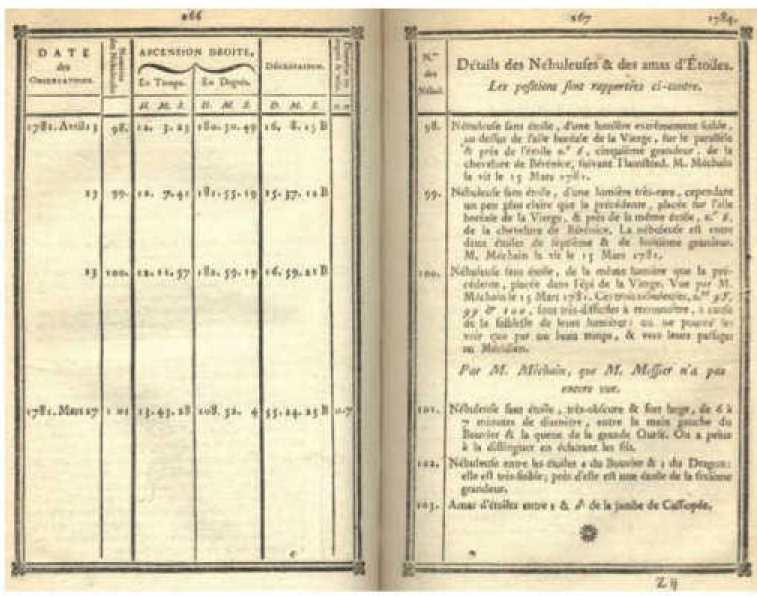
If we had only Facts (1) and (2), we would be sure that M102 is NGC 5866. That galaxy is between Iota Draconis and Theta Boötis — about a third of the way from the former to the latter — and is the *only* galaxy in the area within reach of Méchain's small telescope. (See the star chart on the previous page.)

Fact (3) tells us that Méchain thought either he or Messier had mistaken two observations of M101 for two different objects. I don't think his correction should be taken at face value, however. I think the mistake was different to what he thought.

A decade ago, Stephen James O'Meara argued forcefully that we should accept Méchain's retraction. O'Meara suggests that the second time Méchain observed M101, he measured its position relative to Theta Boötis and then he or Messier, when plotting it on a map, went the wrong way from Theta in right ascension, keeping the correct declination. That would give a position between Theta and Iota, different from


CONNOISSANCE
DES
TEMPS,
OU
CONNOISSANCE
DES
MOUVEMENS CÉLESTES,
Pour l'Année bissextile 1784.
PUBLIÉE POUR LA PREMIÈRE FOIS EN 1679,
Par l'ordre de l'Académie Royale des Sciences,
ET CALCULÉE
Par M. JEAURAT, de la même Académie.
A PARIS,
DE L'IMPRIMERIE ROYALE.
M. DCCLXXXI.

IMCCE (2)


DATE des Observations | ASCENSION DROITE. En Temps. En Degrés. | Déclinaison.

Détails des Nébuleuses & des amas d'Étoiles.
Les positions sont rapportées ci-contre.

Par M. Méchain, que M. Messier n'a pas encore vue.

MYSTERIOUS OBJECT Astro-historians have long debated the particulars of several Messier objects. One of these is M102, listed here in Messier's catalogue with two other bodies that "*M. Messier n'a pas encore vue*" ("Mr. Messier has not yet seen").

PAIR OF STARS *Left:* Charles Messier started publishing his famous astronomical catalogue about a year after this portrait was painted circa 1770, when he was about 40 years old. *Right:* Pierre Méchain, who was 14 years younger than Messier, is depicted here in later life.

PARIS OBSERVATORY LIBRARY (2)

the real M101, and once recognised, the error would justify Méchain's retraction.

That assumes Méchain initially recorded a position measurement, and only later did he or Messier write the description mentioning Theta and Iota. If this is so, it is curious that Messier did not publish a right ascension and declination at all, not even approximately.

The description also mentions a sixth-magnitude star near the galaxy. No such star exists close to M101, but with NGC 5866, depending on how narrowly you interpret 'sixth magnitude,' you have your choice of several, including a magnitude-7.6 star very close indeed.

Most importantly, in his claim that M102 equals M101, Méchain attributes the duplication to "an error in the star charts" — indicating something wrong with the chart itself, not with someone's interpretation of a measurement. (A misprint of omicron for theta is not what he means here; that doesn't solve this part of the problem.) Since he did not name a particular atlas, we must suppose that he and Messier were working with a homemade chart. We know Messier created his own charts of comet paths, as did other astronomers of the time.

What I think happened is that Méchain or Messier used a chart on which one of the circles of right ascension was mislabelled by one hour. NGC 5866 and M101 differ in right ascension by almost exactly an hour, and in declination only slightly. A one-hour mistake in the right direction would make M102 seem to be a slightly imprecise duplicate observation of M101.

The most likely scenario, in my view, is that Méchain saw NGC 5866 but did not measure its position, only noting that it was between Omicron and Theta and close to a sixth-magnitude star. Later, he or Messier found this star field on a chart whose 15-hour circle was erroneously labelled 14, read off the rough coordinates, and noticed that these were close to (just a little more than 1° from) the coordinates of M101. Because this was not at all a precise measurement, Méchain would conclude that it was the same object.

A less likely alternative is that M102 was plotted correctly and M101 was plotted on a separate chart whose 14-hour circle was labeled 15. This, likewise, would make M101 and M102 come out with coordinates only a little more than a degree apart.

There remains Fact (4), Messier's handwritten position, which matches nothing at all. One possible explanation is O'Meara's, already mentioned — that a position measurement was 'flipped' in right ascension relative to Theta Boötis. Another, offered by Frommert, is that NGC 5866's coordinates were misread due to a 5-degree (20-minute) error in labelling or reading right ascension on a map.

I think what Messier really did was much simpler. If Méchain didn't give him a measurement for M102 — only a description saying it was between Theta and Iota — then all Messier could do was to look at his map and select a point midway between the two stars, and write down its position using very round numbers, choosing a right ascension circle marked on his map (14h 40m) and going up to what looked like the right declination (about 56°). That would at least give him something to compare to other people's reports and to use in planning his own observations.

A matter of choice

So I think it's probable, though not certain, that Méchain really saw NGC 5866, complete with the adjacent 6th- or rather 7th-magnitude star, and Messier may have seen it later when confirming the observation. Méchain's later impression that M102 was a duplicate of M101 was a mistake.

We will never have complete certainty, but I would rather add NGC 5866 to the Messier list as M102, with some remaining doubt, than leave it out. We accept other Messier objects that are at least as uncertain, such as M48 and M91. You are free to make up your own mind, but as for me — I finished observing the US Messier list almost 30 years ago — now I need to observe one more object. ✦

"In his claim that M102 equals M101, Méchain attributes the duplication to 'an error in the star charts'."

Michael Covington *is the author of* Astrophotography for the Amateur, Digital SLR Astrophotography, *and other books. By day he is a computational linguist retired from the Institute for Artificial Intelligence at the University of Georgia. He welcomes mail at* ***astro@covingtoninnovations.com****.*

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The PLANET WATCHERS

At the dawn of the Space Age, a worldwide network of astronomers kept vigil on the planets.

KLAUS BRASCH

These days the pages of this magazine are packed with colourful views of Solar System bodies. Many come from spacecraft, of course, but amateur observers around the world also compete for our attention with spectacular images they've acquired using off-the-shelf equipment set up in their backyards and driveways. We celebrate the patience and skill of these talented observers, and professional planetary scientists work closely with them to keep track of planetary goings-on.

But let's also remember that it wasn't always so easy to obtain sharp, detailed images.

In the late 1960s, at the dawn of the Space Age but well before the Digital Age, astronomers at Lowell Observatory spearheaded a remarkably ambitious planetary observing effort. Dubbed the International Planetary Patrol Program (IPPP), the project aimed to continuously monitor atmospheric and other changes on all the major planets. Funded by NASA, it used a network of eight observatories around the world and equipped them with customised cameras and dedicated telescopes designed to produce identical image scales. No collaborative effort of this extent had been attempted before. In fact, during 1969–70, its first year of operation, the patrol obtained as many usable images of Mars and Jupiter as had been taken during the preceding half century.

It's important to appreciate the scientific and technological context in which the program was conceived. Professional astronomers had largely abandoned studies of the Moon and planets in the first half of the 20th century in favour of galactic astronomy and astrophysics. Consequently, by the early 1960s, we lacked precise rotation periods for Mercury and Venus, nor did we fully understand the circulation of Venus' opaque cloud deck. Despite more than a century of visual and photographic work by amateurs and some professionals, astronomers still lacked quantitative information regarding many aspects of Jupiter's

The global IPPP network routinely recorded the planets on a nearly hourly cadence. This sequence shows Mars on May 27–28, 1969.

Left: **The Space Age has brought us close-up images of the planets, such as this Cassini spacecraft view of Saturn. But for years a network of observatories kept an eye on our Solar System neighbours.** M.MALMER/CASSINI IMAGING TEAM

atmosphere, such as oscillations in the Great Red Spot and the change in rotation period of the Jovian cloud deck as a function of latitude. Similar uncertainty existed about Saturn's atmosphere and ring system. The advent of the Space Age, however, triggered renewed interest in Solar System astronomy and led to observational efforts such as the IPPP.

Our understanding of Mars in the early 1960s was also at a crossroads. We didn't understand the nature of the planet's variegated surface features, its clouds, dust storms, or the true composition and seasonal variations of its polar caps. As William Sheehan points out in *The Planet Mars: A History of Observation & Discovery,* although Percival Lowell's canal theory had largely fallen into disrepute, his notions about water, atmosphere and vegetation on Mars persisted, at least in popular imagination. This, coupled with the start of the space race and the promise of human exploration to the Moon and later Mars, left a glimmer of hope that the Martian environment might be relatively benign. Thus, as late as 1965, the idea persisted that the colour and apparent seasonal darkening of some Martian features might be due to lichen or similar vegetation.

Solar System sentinels

William A. Baum (1924–2012), a remarkably versatile investigator and pioneer in many areas of astronomy, led the IPPP team. Other key contributors included cartographers Leonard J. Martin (1930–97) and Jay L. Inge (1943–2014), and astronomer Charles 'Chick' Capen (1926–86).

The IPPP had a very specific goal: to secure and archive uninterrupted planetary observations in support of the soon-to-follow NASA planetary space missions. The global network consisted of six and later eight observatories equipped with telescopes having 61- to 67.3-cm apertures, including classical refractors such as Lowell's 61-cm (24-inch) Clark and four specially built 61-cm f/75 Cassegrain reflectors.

Baum's team also designed advanced 35-mm film cameras that incorporated innovative focusing, guiding, colour-filter selection and calibration. Whenever possible, observers recorded the planets hourly at each station on Kodak 2498 RAR film, in 14-exposure sequences through red, green, blue and ultraviolet filters, with the date, time, observer, location and colour stamped on each frame. Later, technicians in Flagstaff developed all the film under tightly controlled conditions. By the time the IPPP

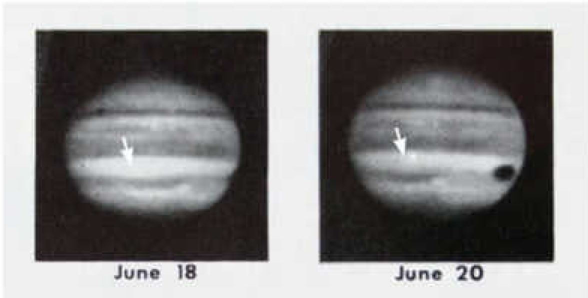
S&T: GREGG DINDERMAN

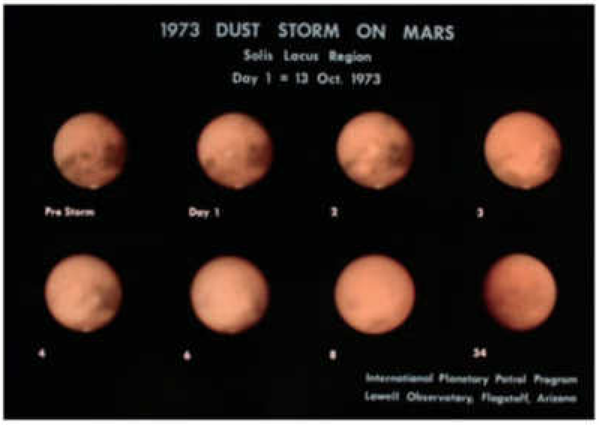
The International Planetary Patrol Program used a global network of observatories that could monitor planetary activity around the clock.

International Planetary Patrol Program Observatories

1. Lowell Observatory, Flagstaff, Arizona
2. Mauna Kea Observatory, Hilo, Hawai'i
3. Mount Stromlo Observatory, Canberra, Australia
4. Perth Observatory, Bickley, Australia
5. Astrophysical Observatory, Kodaikanal, India
6. Republic Observatory, Johannesburg, South Africa
7. Cerro Tololo Inter-American Observatory, Chile
8. Magdalena Peak Station, New Mexico State University, Las Cruces

Right: **A sequence of ultraviolet-filtered images shows the development of a disturbance (arrowed) in Jupiter's South Equatorial Belt. The dark oval (June 20th, far right) is the Great Red Spot.**



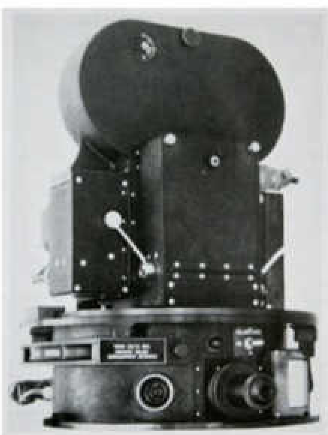


LOWELL OBSERVATORY (3)

Above: **The Solis Lacus region on Mars erupts with a major dust storm in this month-long sequence of IPPP tri-colour composite images. Day 1 is October 13, 1973.**

ended in the late 1970s, its observers had obtained 1.2 million individual planetary images.

While IPPP participants monitored all major planets, their most productive results involved Mars. A half century of prior visual and photographic work had documented numerous atmospheric phenomena, including: yellow, white and blue clouds; dust storms; polar hazes; and a recurring W-shaped cloud over the Tharsis region. Since analysts were unsure about the exact nature of most Martian atmospheric features at the time, they classified them on the basis of the colour or wavelength at which they appeared most prominently.



Above: **Observers used this custom-designed, semi-automated, 35-mm film camera for all IPPP planetary photography.**

The IPPP's observers documented major dust storms in 1971 and 1973 and continued to scrutinise the Red Planet up to the Viking spacecrafts' 1976 arrivals. The earlier storm coincided with the arrival of Mariner 9 and blanketed the orbiter's view of the Martian surface for several weeks. IPPP imagery helped establish not only the dynamics and speed of the storm's development but also enabled understanding of climatic changes on the planet, including cloud formation and seasonal variations in the polar caps.

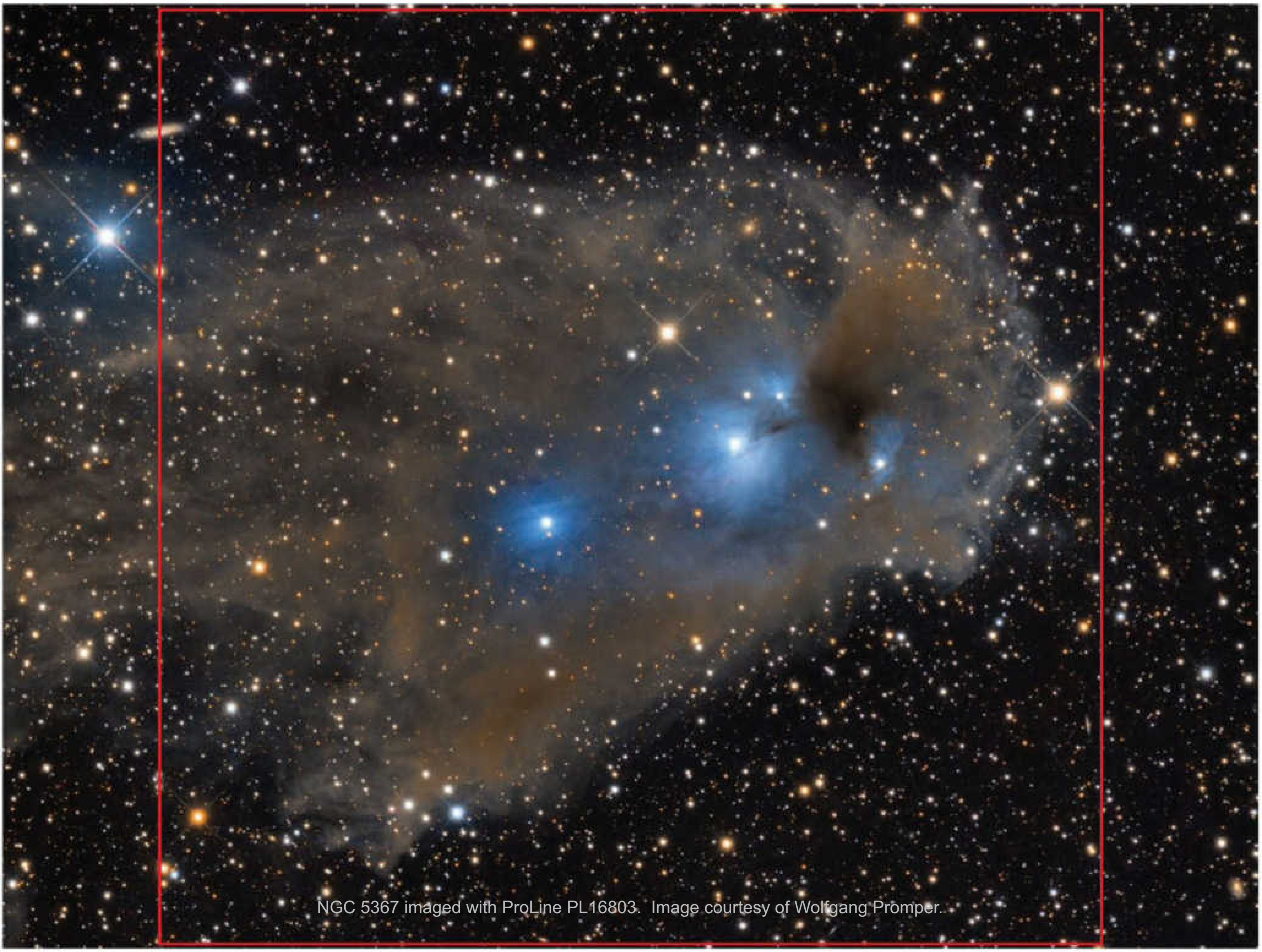
We learned to distinguish between polar ice and the often more extensive polar 'hood' of clouds that extended to lower latitudes. Results also showed conclusively that the 'seasonal' variations in the albedo features — the ones that had so intrigued earlier observers — resulted entirely from changes in wind patterns and local features revealed and obscured by blowing dust. When planetary astronomers compared the familiar features studied telescopically for more than three centuries with spacecraft-derived images, they found only minimal correlation with Martian topography — and no indication of surface vegetation or the contentious 'canals'.

Images of Jupiter constituted more than half of the IPPP's database, yielding a wealth of information about the planet's cloud deck. The results confirmed both abrupt and gradual atmospheric changes, including large- and small-scale disturbances, a 90-day oscillation in the longitude of the Great Red Spot, and rotational velocities in cloud features that correlated with both their colour and latitude. IPPP coverage overlapped with the Pioneer 10 and 11 fly-bys of Jupiter in 1973 and 1974, respectively, showing that many dark features are the tops of vertical convection cells. These data formed the basis for future studies and modelling of Jupiter's dynamic atmosphere.

Observers also examined Saturn's ring system to probe the light-scattering properties of its particulate constituents. This effort revealed that particles in the A and B rings have similar compositions but different densities, information that anticipated the arrival of Pioneer 11 at Saturn and its passage through the planet's rings.

The program collected far fewer photographs of Venus than of Mars or Jupiter, due to the inherent difficulty of observing this planet well. However, some excellent ultraviolet sequences helped confirm previous reports that the planet's upper atmosphere exhibited retrograde rotation, as did the planet's globe, but with a period of just 4 days rather than the 243 days of Venus itself. This laid the groundwork for subsequent modeling of the planet's unusual wind-shear patterns.

This pioneering program wound down in the late 1970s, superseded both by better electronic imaging and photometric technology and by close-up exploration with space probes and landers. Nevertheless, the IPPP provided crucial information that helped get the maximum return from those missions. Moreover, its broad, extensive international co-operation became the model for the host of global astronomical collaborations that would follow. ✦



NGC 5367 imaged with ProLine PL16803. Image courtesy of Wolfgang Promper.

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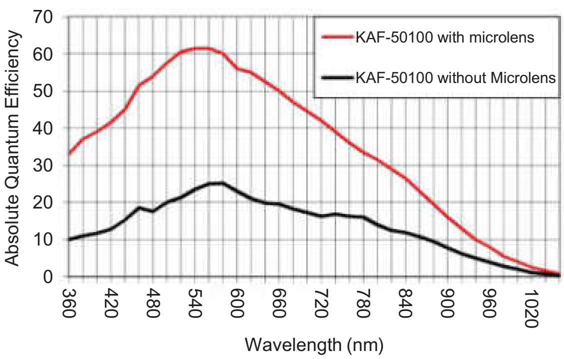

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THE ASTROLABE: Astronomy's first hot app

THE TIME MUSEUM

ASTRONOMICAL JEWEL This German astrolabe, made in Nuremberg in 1532, has an ornate brass rete that supports 27 points. The points form a star map; each is labelled with the name of a star. Near the bottom, for instance, are *Procion, Oculus Tauri* (Eye of Taurus), and *Pes Sin(ister) Orionis* (left foot of Orion). An astrolabe's sky is mirror-imaged right for left. The star-map grillwork, including the ecliptic circle, turns above a plate marked with, among other things, a fine grid of altitudes and azimuths above the user's horizon.

Loaded with features, an ancient analogue computer replicates the sky's workings.


BRUCE WATSON

On a warm November evening, I consult my astronomy app to see what the night sky has in store for me. Star by star, this little wonder spreads the constellations before me. But this particular device has neither screen nor software. It is an astrolabe.

Since antiquity, this ingenious tool has accurately modelled the movements of the Sun and the stars. Before there were good clocks, its main use was to tell the time. Now that we always know the time, it can work backward to tell us where the Sun and stars are, or will be. It's the forebear of the ship's sextant and the modern skygazer's handy planisphere. Users once relied on it to tell the astrological house of the Sun, the 28 lunar stations, when to perform the Islamic prayers, and the 'unequal hours' that divided the changing days and nights into perfect twelfths, different for each day (standard practice before clocks, then continued for astrology and magic).

It also solved everyday trigonometry problems, measured heights and aided surveyors, and performed other functions depending on the design. It was feature-packed. "All the conclusions that can be found, or might possibly be found in so noble an instrument as an Astrolabe, be unknown perfectly to any mortal man in this region," marvelled Geoffrey Chaucer in 1391. Kind of like my smartphone.

Astrolabes are now found in museums rather than observatories or travellers' packs. Reposing in glass cases, their golden wheels within wheels conjure up images of bearded men in tunics charting horoscopes. Before the telescope, the astrolabe was the icon of astronomy: the proud possession of kings and princes, doctors, geographers, would-be wizards with an astrological bent, and of course astronomers themselves.

If I wanted to understand how skywatchers in ancient Greece, Arabia, Persia or Renaissance Europe sensed the celestial clockwork, I would have to learn the astrolabe. But where could I get one?

It turns out you can buy a modern brass astrolabe on eBay or Amazon for about $250. A plastic model goes for $100. A craftsman in Germany will forge a stunning brass replica for a mere $1,500. And the true antiques? An immaculate astrolabe crafted in 1505-06 for the Ottoman Sultan Bayezid II recently sold at Sotheby's for US$1.56 million. It's no wonder that fakes abound.

I chose a $40 plastic-laminated model, custom printed on card stock for my home latitude and longitude, from James E. Morrison of Rehoboth Beach, Delaware, who does business as Janus. (It's shown on page 39.)

While waiting for it to arrive in the mail, I learned how this ingenious device put Sun, night and time into the palm of a hand.

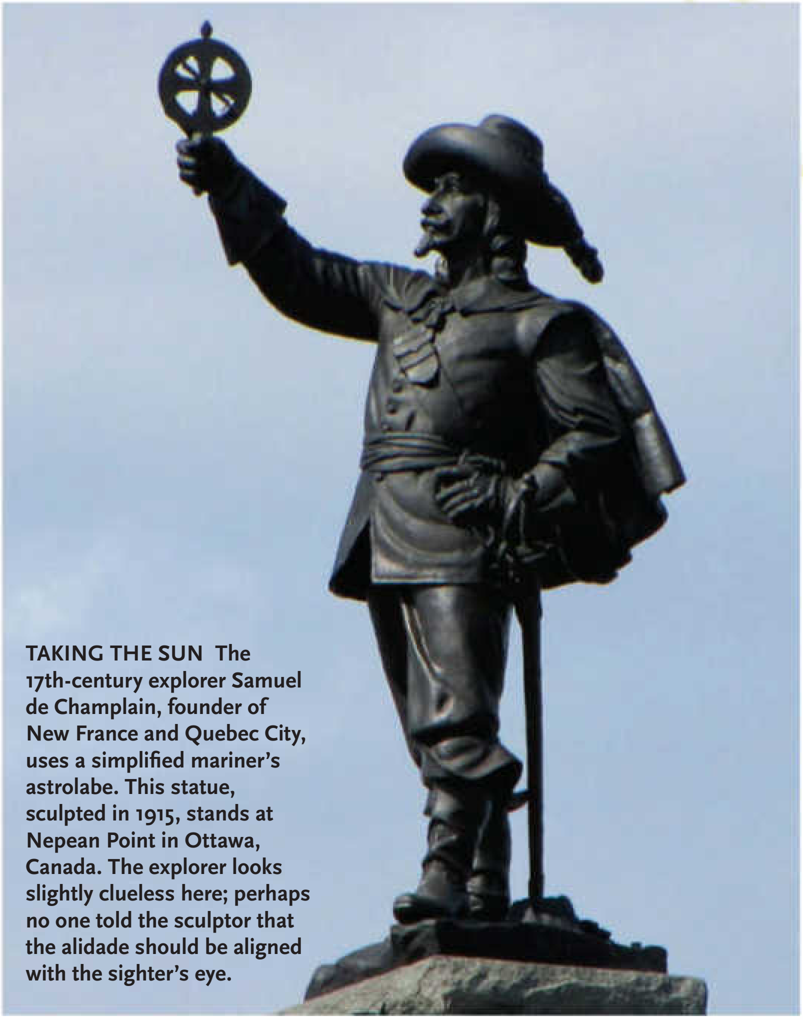
Ancient knowledge

No one is sure who invented the astrolabe. A likely candidate is the Greek astronomer Hipparchus, who worked on the Isle of Rhodes around 150 BC, but it evolved in complexity and usefulness over many centuries. The word *astrolabe* is from the Greek for 'star taker.' Most varieties have the same basics: a sighting device, a movable star map in the form of a metal network including a finely scaled zodiac ring; a flat, stereographic projection of the sky's altazimuth coordinate grid from horizon to zenith; and a finely divided circular scale of hours around the outside.

Astrolabes reached their maturity during the Golden Age of Islam, 700–1200 CE. After steering Arab sailors to Spain, they entranced travellers who brought them to northern Europe around 1000 CE. Marco Polo saw many in China during his travels in the late 1200s. They democratised astronomy. Well-established royal astronomers used big, wooden or bronze armillary spheres to track the Sun, planets, and stars more precisely, but the astrolabe let any well-off amateur do it with a brass disc hung on his belt.

Ancient astrolabes relied on knowledge of the zodiac, but the version I bought from Janus (he sells two) was his modernised one that leaves astrology behind. Instead of Roman numerals, the 24 hours around its rim are ordinary numbers. And instead of degrees within houses of the zodiac, the ecliptic circle is marked with calendar months and days. But otherwise, my laminated model matches the classics.

The base, known as the *mater* or mother, encloses a disk, the *tympan* or *climate*, with fine, off-centre grid lines. The circles of this grid, known by their Arabic term *almucantars,* are altitude lines above your local horizon. The arcs cutting across them from horizon to the zenith mark azimuths, or compass directions (nowadays measured in degrees counting clockwise from north). Traditionally, a fine astrolabe came with a set of interchangeable tympans for use at different latitudes. On mine, the mater and tympan are a single layer printed for my own latitude exactly.



TAKING THE SUN The 17th-century explorer Samuel de Champlain, founder of New France and Quebec City, uses a simplified mariner's astrolabe. This statue, sculpted in 1915, stands at Nepean Point in Ottawa, Canada. The explorer looks slightly clueless here; perhaps no one told the sculptor that the alidade should be aligned with the sighter's eye.

D. GORDON E. ROBERTSON / WIKIMEDIA COMMONS

The heart of an astrolabe is its star map or *rete,* from the Latin for net. The classical rete was a rotating metal filigree, including the circle of the ecliptic, with labelled metal points representing the positions of bright stars: Rigel, Sirius, Capella, Vega. My rete is clear plastic with stars printed on it.

Turn the rete and stars rise and set, crossing the horizon-edge of the tympan's nested circles. The ecliptic circle among the stars travels with them. The ecliptic is the Sun's annual path around the sky, so when your date marked on this circle rises and sets, so does the Sun.

Finally, an astrolabe usually has two rotating rulers, one on each side. The ruler on the back is the *alidade,* a sighting device. It sometimes had little uprights with holes or sight notches for precision. The ruler on the front is just called the *rule,* used for matching a reading on one part of the face to an index on another part — in particular the outer circle of hours.

Once I learned its parts and history, I was eager to take my astrolabe outside. But the arcs and wheels hardly explained themselves. Luckily, Janus' instruction book was easier than I expected.

Under the stars

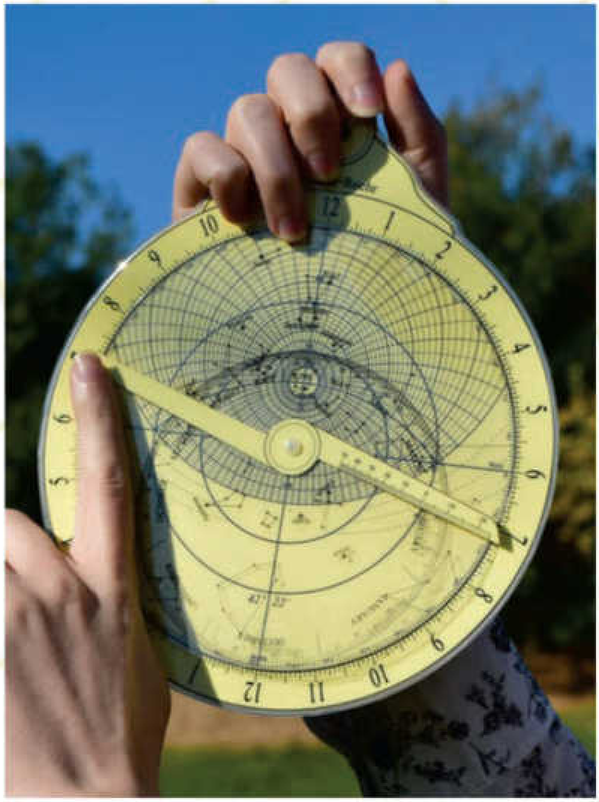
To check the night's parade of the heavens, I first wheeled the rete so that my date on the edge of the ecliptic circle touched the west side of the horizon arc: sunset! Using the rule to point from there to the rim told me the sunset time.

Or rather, it told me sunset's *local apparent solar*

SEBASO / WIKIMEDIA COMMONS

WORKS IN REVERSE **The famous astronomical clock on Prague's Old Town Hall, installed in 1410, is an astrolabe driven by clockwork to show the position of the Sun and Moon. It also tells the time in three systems: modern hours (roman numerals), hours from sunset (outer gold numbers), and the ancient unequal hours (black numbers). Here, the Sun is approaching the horizon of sunset (*occasus*) and the Sun's subterranean domain in twilight (*crepusculum*). In the upper corners, Death rings his bell every hour and Pride, Greed, and Lust shake their heads in reply, "No, not yet."**

S&T: SEAN WALKER (2)



CELESTIAL SIGHT **Like a telescope today, an astrolabe in ancient and medieval times marked you as an astronomer. It too required special knowledge and a good eye. This is the modern astrolabe described in the text.**

time (sundial time). That's what everyone used in the centuries before accurate clocks and fast communication. Since I want modern clock time instead (which runs with uniform speed and applies across an entire time zone), adjustments are needed. Custom-printed on the back is my permanent correction in minutes for the longitude of my home. Thanks, Janus! Also on the back is a graphical scale for finding the Equation of Time correction for any date, using the alidade as a rule. The Equation of Time adjusts for the fact that Sun time runs as much as 16 minutes fast or slow around the year, due to the tilt of Earth's axis and the ellipticity of its orbit. Thanks again.

And when daylight-saving time is in effect, I need to add an hour. For astronomers who want to track the Sun and stars, rather than catch a train or arrive on time for a meeting, modern time is complicated!

The astrolabe, I learned, also reads past and future. Aligning different dates on the ecliptic to the horizon, I could read the time of sunrise or sunset for any day of the year. Or I could pick a star — Arcturus, say — and spinning to other dates and times, see where it would stand above or below the horizon. By the time I stepped out on that warm night I was a 21st-century Hipparchus, ready to take the stars.

To check the time, I spotted Aldebaran and held the astrolabe aloft by its two-ring chain, letting gravity align the vertical. On the back side, I carefully nudged the alidade to point exactly at Aldebaran. I then read, where the alidade crossed the protractor scale on the outermost rim, Aldebaran's altitude above the horizon. I turned over my astrolabe, found Aldebaran on the clear plastic rete, and positioned the star at that altitude in the east on the grid of almucantar circles.

Holding the rete in place, I found my date on its ecliptic circle and aligned the rule to that date. Where the edge of the rule met the outer rim, I read the time: a hair short of 9:55. Call it 9:54. Apply my longitude correction, read the Equation of Time correction for the date from the scale on the back, and I had 9:31 p.m.

I checked my smartphone app. My astrolabe was a minute slow. Not bad for a paper-and-plastic replica of a timepiece older than Ptolemy. Maybe I was a bit lucky on my first try, but to check and improve my accuracy I can take several star-sightings and average them.

It seems like a lot of work to get the time, but imagine if it was the only way you could. Or if you wanted to know when the Sun would rise on the date of an impending battle, or how the stars were arrayed at the time of your patron's birth. Early sailors used the astrolabe for navigation, especially after a streamlined mariner's version made it easy to 'shoot the Sun'. The sextant (recently reintroduced in the U.S. Navy as a backup in case of cyberattack on navigational satellites) is merely a further refinement.

Ancient astrolabes performed still more wonders. A shadow square on the back enabled calculations of distance or height. The degree scale around the rim served as a surveyor's protractor. Arab astrolabes found the direction of Mecca. But my modern version seems wondrous enough. ✦

Bruce Watson *is the author of* Light: A Radiant History from Creation to the Quantum Age *(Bloomsbury, February 2016).*

▲ **BUDGET RITCHEY**

Industry newcomer Third Planet Optics rolls out a series of Ritchey-Chrétien astrographs for the budget-minded astrophotographer. The largest of the series, the TPO 40-cm f/8 Ritchey-Chrétien Truss Tube OTA, is built to resolve tiny features in your deep sky images. This OTA is manufactured from CNC-machined aluminium and carbon-fibre truss tubes to ensure collimation stability when pointed anywhere in the sky. Its quartz optics utilise 99% reflective dialectric coatings and will reach thermal equilibrium quickly with the aid of three cooling fans. The telescope comes with a 75-mm, dual-speed, linear bearing Crayford-style focuser with a generous back focus distance of 400-mm.

Third Planet Optics

▼ **MEGA REDUCER**

Astro-Physics announces the Quad Telecompressor Corrector for its 130 StarFire GTX and EDFGT telescopes. This large-format 0.72× reducer shortens the focal length of the 130-mm f/6.3 StarFire GTX from 819 to 598 mm (f/4.6), enabling you to record wider expanses of the sky. The four-element Quad TCC fits into the scope's 90-mm focuser, producing pinpoint stars across the entire field of a 35-mm sensor, and also works with Telescope Engineering Company (TEC) refractors with additional spacers offered by Astro-Physics.

Astro-Physics
astro-physics.com

3D EYEPIECES

Denkmeier unveils its most unique eyepiece set, the L-O-A 21. The L-O-A (Lederman-Optical-Array) is a patent-pending design that simulates a 3D view through telescopes equipped with binoviewers. Users simply rotate the 'active' eyepiece when aimed at a deep sky target until the subject appears to be floating among the stars in the field. Six levels of 3D depth are possible depending on the settings used. Each L-O-A 21-mm eyepiece has a generous 65° apparent field and comes in bolt-style eyepiece container. See manufacturer's website for additional details.

Denkmeier
deepskybinoviewer.com

New Product Showcase is a reader service featuring innovative equipment and software of interest to amateur astronomers. The descriptions are based largely on information supplied by the manufacturers or distributors. *Australian Sky & Telescope* assumes no responsibility for the accuracy of vendors' statements. For further information contact the manufacturer or distributor.

Jonathan Nally
Binocular Highlight

A tale of two clusters

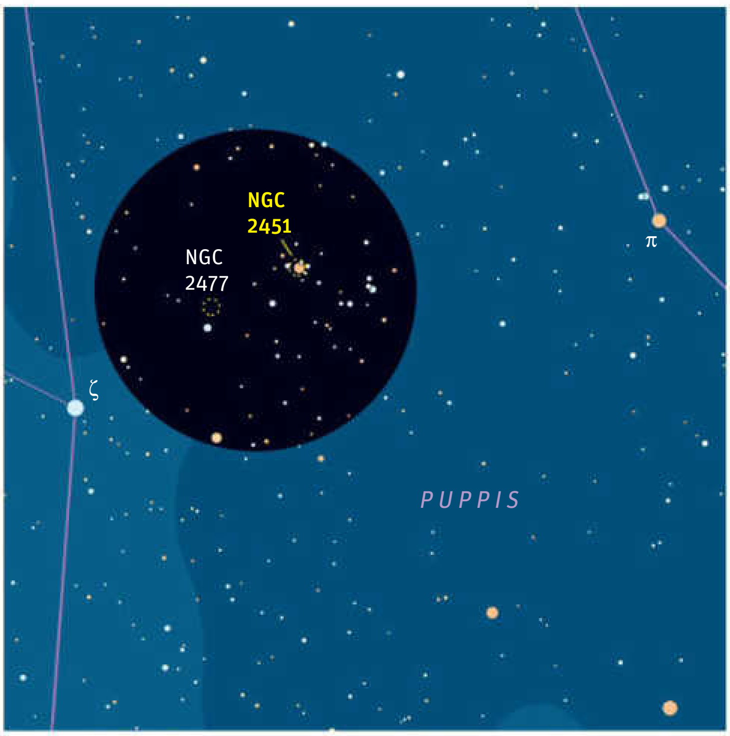
Puppis is one of those constellations that has an embarrassment of riches for all stargazers, whether you use a telescope, binoculars or just the naked eye. Star clusters are its forte, and this month we'll concentrate on two of them that are ideal for binocular viewing — NGC 2477 and NGC 2451. Although we've looked at these clusters before, many years ago, it's time for them to return to the limelight, particular with Puppis nice and high in our skies at the moment.

NGC 2451, sometimes called the Stinging Scorpion, is actually two clusters superimposed on the line of sight — 2451A is 670 light-years away, while 2451B is about 1,200 light-years distant.

The brightest member of 2451B is the binary star c Puppis, magnitude 3.6 and about 1,100 light-years from Earth. The larger star of the pair is a giant or supergiant, variously described as yellowish, orange or red, while the companion is a blue main-sequence star. They're too close together to be seen separately, even with a large telescope, but the pair makes a fine sight through binoculars — particularly as a study in colour contrast with the other members of the group.

NGC 2477 is at least twice as far away as 2451B, and is a fine object for binoculars. Comprising about 300 stars, it is too far south to have made it onto Messier's famous list — but then, that goes for a lot of the objects in our magnificent southern skies.

Together, 2451A and B, and 2477, are easy to spot and will reward you for the time you spend observing them. ✦



USING THE STAR CHART

WHEN

Late January	1 a.m.
Early February	Midnight
Late February	11 p.m.
Early March	10 p.m.

These are daylight saving times. Subtract one hour if daylight saving is not applicable.

HOW

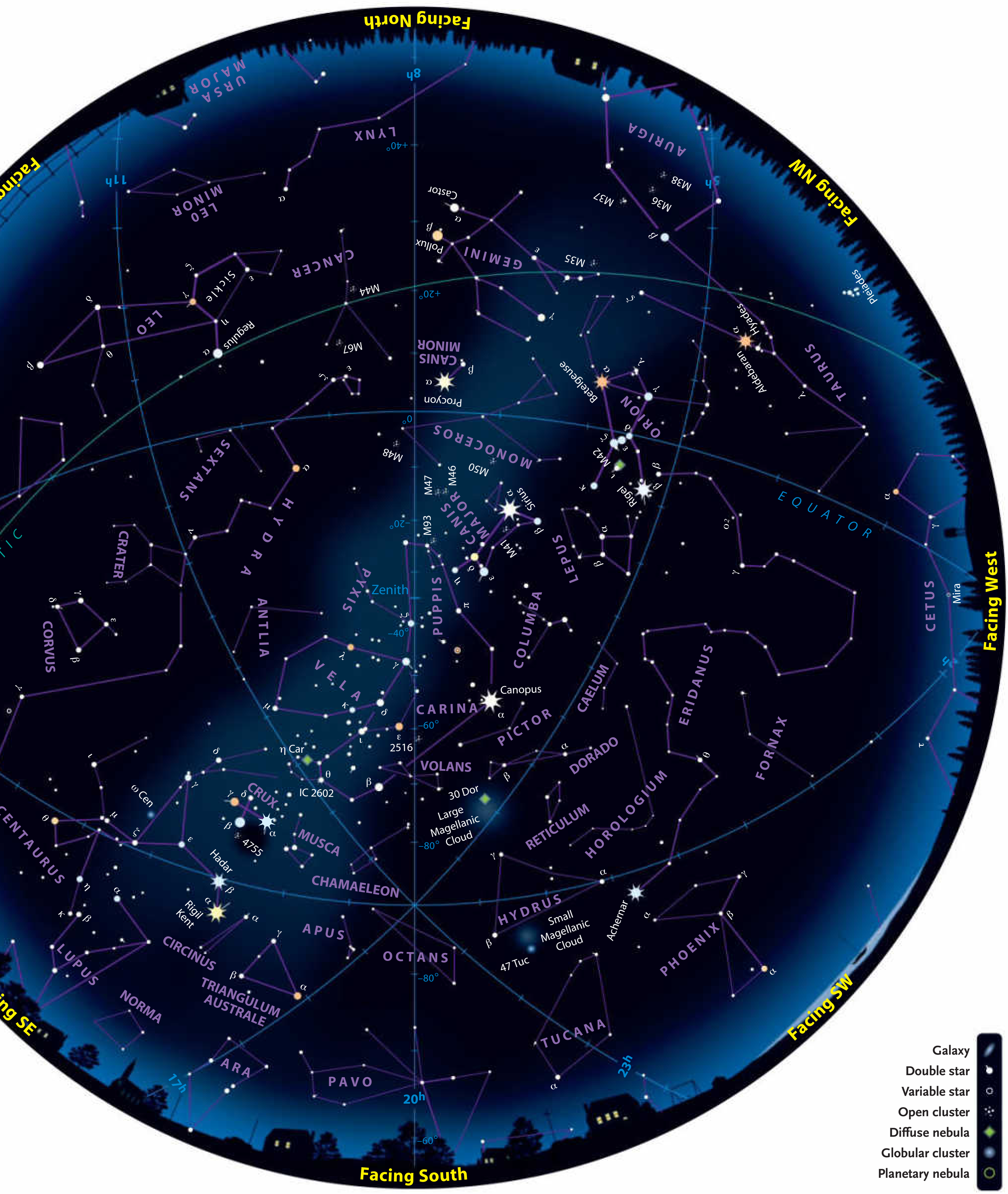
Go outside within an hour or so of a time listed above. Hold the map out in front of you and turn it around so the label for the direction you're facing (such as west or northeast) is right-side up. The curved edge represents the horizon, and the stars above it on the map now match the stars in front of you in the sky. The centre of the map is the zenith, the point in the sky directly overhead.

FOR EXAMPLE: Turn the map around so the label "Facing NE" is right-side up. About halfway from there to the map's centre is the bright star Procyon. Go out and look northeast halfway from horizontal to straight up. There's Procyon!

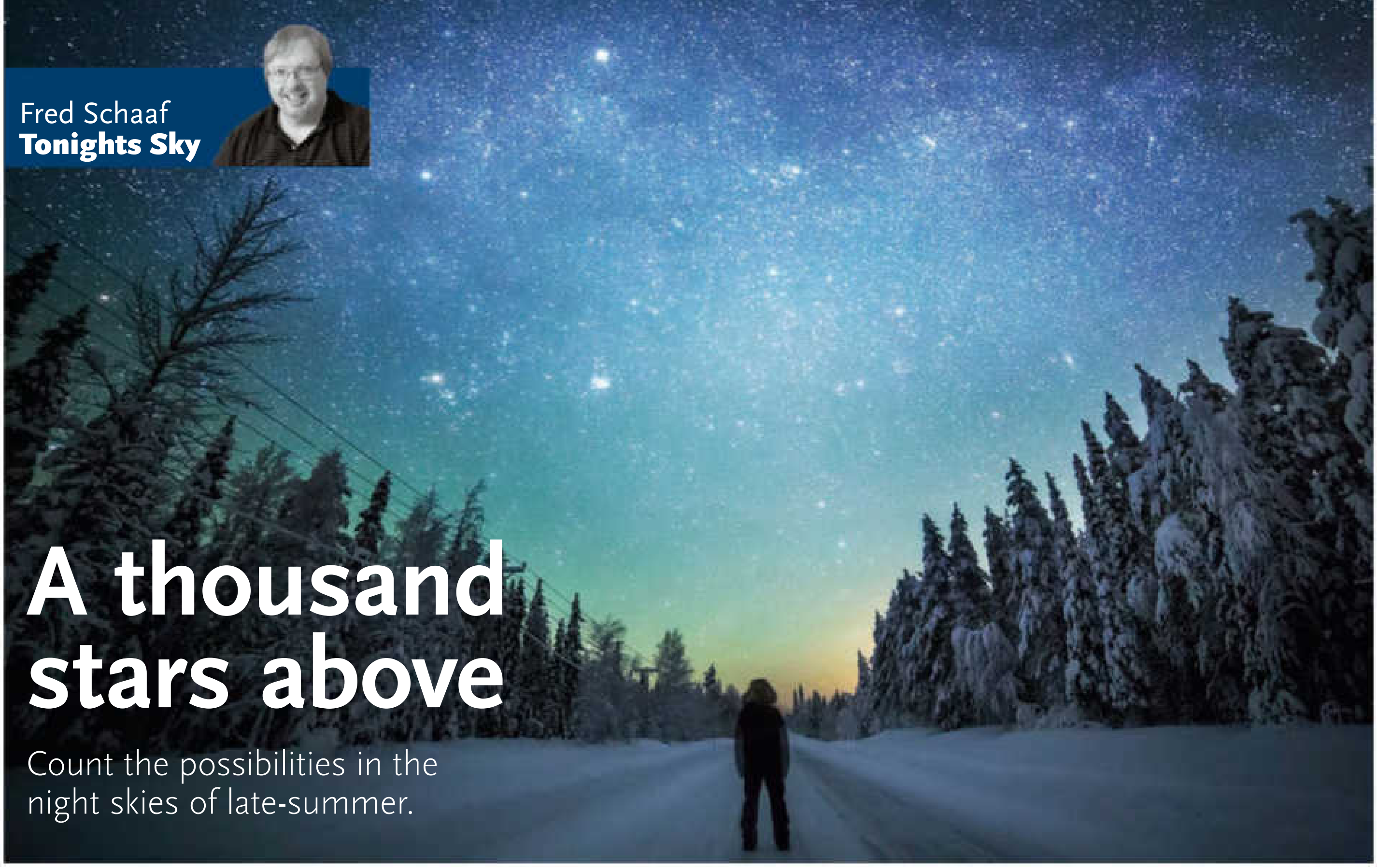
NOTE: The map is plotted for 35° south latitude (for example, Sydney, Buenos Aires, Cape Town). If you're far north of there, stars in the northern part of the sky will be higher and stars in the south lower. Far south of 35° the reverse is true.

ONLINE

You can get a sky chart customised for your location at any time at SkyandTelescope.com/skychart



Facing North
Facing NW
Facing West
Facing SW
Facing South
Facing SE
URSA MAJOR
LYNX
AURIGA
LEO MINOR
CANCER
GEMINI
LEO
Sickle
Regulus
Castor
Pollux
M44
M67
M35
M36
M37
M38
Pleiades
Hyades
Aldebaran
TAURUS
CANIS MINOR
Procyon
Betelgeuse
ORION
MONOCEROS
M48
M50
M47
M46
M93
M42
Rigel
Sirius
CANIS MAJOR
M41
SEXTANS
HYDRA
CRATER
CORVUS
ANTLIA
PYXIS
Zenith
PUPPIS
LEPUS
COLUMBA
EQUATOR
CETUS
Mira
ERIDANUS
FORNAX
VELA
Canopus
CARINA
CAELUM
PICTOR
DORADO
η Car
2516
IC 2602
VOLANS
CRUX
MUSCA
4755
30 Dor
Large Magellanic Cloud
RETICULUM
HOROLOGIUM
ω Cen
CENTAURUS
Hadar
Rigil Kent
CHAMAELEON
HYDRUS
Achernar
Small Magellanic Cloud
47 Tuc
PHOENIX
LUPUS
CIRCINUS
APUS
OCTANS
TRIANGULUM AUSTRALE
NORMA
TUCANA
ARA
PAVO
8h
11h
5h
17h
20h
23h
+40°
+20°
0°
−20°
−40°
−60°
−80°
Galaxy
Double star
Variable star
Open cluster
Diffuse nebula
Globular cluster
Planetary nebula



Fred Schaaf
Tonights Sky

A thousand stars above

Count the possibilities in the night skies of late-summer.

TIINA TÖRMÄNEN

Take me into your loving arms
Kiss me under the light of a thousand stars
Place your head on my beating heart
I'm thinking out loud
Maybe we found love right where we are.
— Ed Sheeran and Amy Wadge, *Thinking Out Loud*

I like the mention of "the light of a thousand stars" in the chorus of Ed Sheeran's hit song. Not fewer than a thousand stars, so we know these young lovers are blessed with a sky that's at least relatively free of light pollution. But the song also doesn't engage in unknowledgeable hyperbole and claim a million stars.

The more I've thought about it, the more intriguing I've found the concept of a thousand stars. We can explore the topic not just mentally indoors but also visually outdoors — where the bright traditional constellations of summer offer some wonderful opportunities to see numerous stars, both with the naked eye and with optical aid.

How many thousands of stars can be seen with the naked eye? The answer depends first on sky conditions — including light pollution, of course — both near the zenith and at lower altitudes in the sky, where more light is absorbed and scattered. But there's another factor as well: the viewer's observing skill. It takes practice to get better at using 'averted vision' — looking slightly away from a target object so that its light falls on the outer parts of the retina where there are greater numbers of light-sensitive rod cells.

I've always told people that more than just one or two thousand stars can be seen under ideal conditions with the naked eye. Perhaps the ancient Greeks used a special word, 'myriad' (meaning 10,000), because the most prominent display of great number in nature was the stars. They might have estimated that roughly 'a myriad' of stars could be seen in the sky.

But exalting in a sky of just a thousand stars has its own merits. A 'thousand' is a determinate number, and it's within the reach of people with less-than-ideally dark skies. The *Millennium Star Atlas* tells us there are 893 stars at magnitude 4.49 or brighter and 2,822 at 5.49 or brighter. If the naked-eye limit is supposed to be 6.5, the total grows to 8,768 naked-eye stars. But some observers have seen stars as dim as magnitude 8.0 with the naked eye, so we can imagine a number closer to a myriad.

Some conditions (such as snow cover, for those who get it) can worsen our faint limit by several magnitudes. Even the light produced by a fairly dark night sky can make our limiting magnitude markedly brighter. To see the faintest stars, cup your hands around your eyes or block as much of the sky from view as possible with trees or dark buildings.

On late summer evenings, the region to keep in clear view is the group of constellations centered on Orion. No one constellation has 1,000 naked-eye stars in it, but if you take the stars brighter than 6.5 in the Orion group — Orion (204), Taurus (223), Gemini (119), Canis Minor (47), Canis Major (147) and, lower in the north, Auriga (152). Add them together, and you get 892. Add the 73 stars of Lepus and you're closer to 1,000. Add Monoceros (138) and you're over a thousand.

According to the *Millennium Star Atlas,* the richest areas of the heavens (regions such as Crux and Cygnus) can display, in ideal conditions, more than 3,000 stars in a typical 7×50 binocular field. In summer, try the region of Orion's Belt and Sword, or parts of Puppis, to see a thousand stars through binoculars. It's a glorious sight. ✦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Five planets on parade

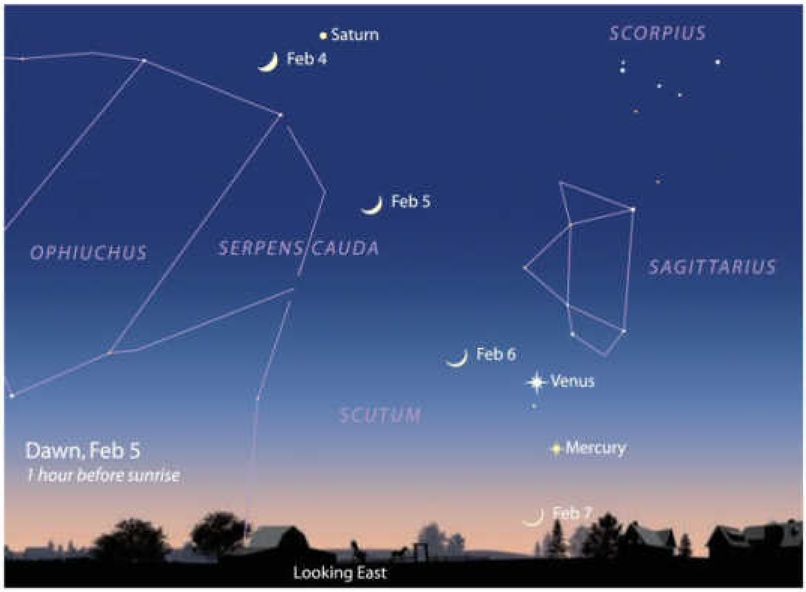
Mercury, Venus, Mars, Jupiter and Saturn all in the sky together.

February will begin with all of the naked-eye planets visible for most of the night. Jupiter will rise around 9:00pm, followed by Mars just before midnight, Saturn just after 1:00am, and Venus and Mercury between 3:00 and 4:00am before the dawn twilight begins. That means all of the planets will be in the sky at once — how very convenient!

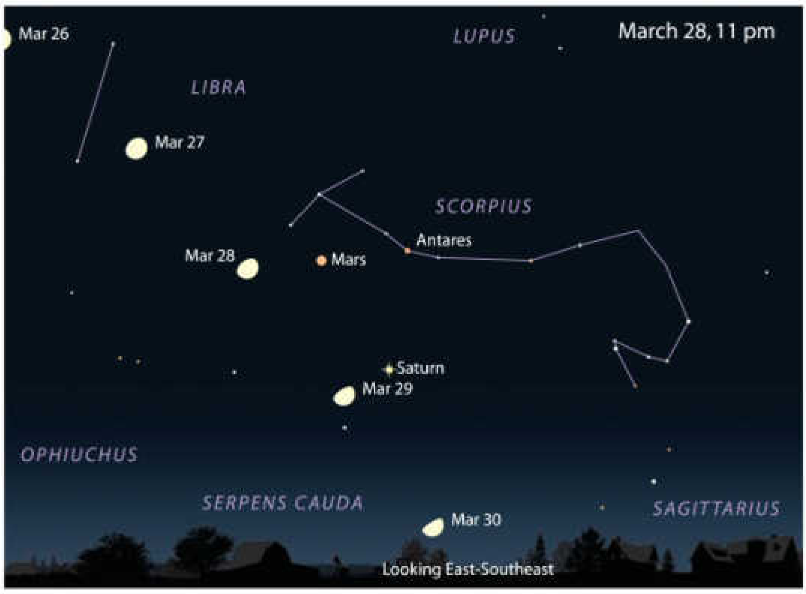
February will be a great time to see **Mercury** in the eastern morning sky, where it will be in company with Venus for most of the month. As the weeks move on and we enter March, the innermost planet will have dropped lower toward the horizon, and soon will be lost in the Sun's glare.

Venus will be nice and bright to the east in the morning sky. Look for the thin crescent Moon nearby on February 6 and 7 (along with Mercury, as mentioned above), as well as March 7 and 8.

Mars will rise at around 11:30pm at the beginning of February, and 9:00pm by the end of March. On February 1 and 2, the Red Planet will be joined by the quarter Moon, and on the 3rd it will appear close to the star Alpha Librae. By the beginning of March, Mars will be halfway between Libra and Scorpius. The Moon will be close by on March 28.



Venus and Mercury will be in close company in the eastern morning sky at the beginning of February, with the thin crescent Moon nearby on the 6th and 7th.



Yellow Saturn and red Mars will be relatively close to each other at the end of March, with spectacular Scorpius riding above them.

As mentioned above, **Jupiter** will rise at mid-evening in early February, but by the time March comes around it will rise around the time of sunset. This is because the giant planet will reach opposition on March 8. Opposition is when a planet and the Sun are on opposite sides of the Earth... the practical upshot of which is that as the Sun goes down in the west, the planet rises in the east, and therefore will be visible all night long. See how many of the Galilean moons you can spot with a pair of binoculars.

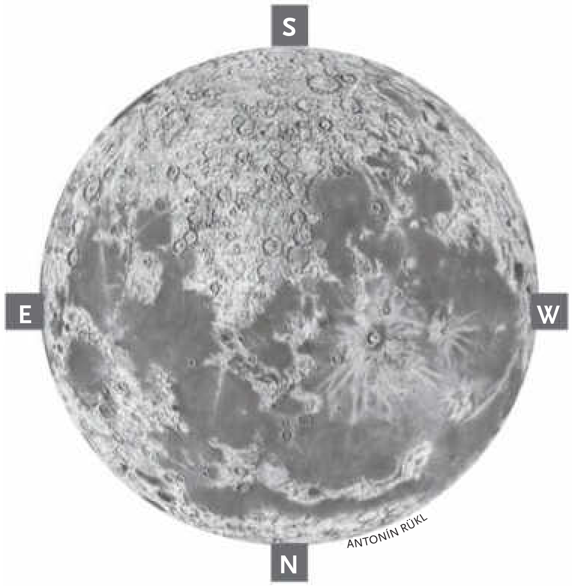
The ringed giant, **Saturn**, will be a fine sight for planet watchers during February and March, rising earlier each night (at around 10:00pm by the end of March). A small telescope will show its rings. Watch for the Moon nearby on February 4 and March 3 and 29.

Finally, in March we'll reach another milestone for our own planet — on the 20th we'll be at the southern autumnal equinox, marking the halfway point between mid-summer and mid-winter. ✦

Events Of Note

Feb	1	Mars 3° south of the Moon
	3	Mars 1.2° NE of Alpha Librae
	3	Antares 10° south of the Moon
	4	Saturn 3° south of the Moon
	6	Venus 4° south of the Moon
	7	Mercury 4° south of the Moon
	16	Aldebaran 0.3° south of the Moon
	22	Regulus 3° north of the Moon
	24	Jupiter 1.7° north of the Moon
	27	Spica 5° south of the Moon
Mar	1	Mars 4° south of the Moon
	2	Antares 10° south of the Moon
	2	Saturn 4° south of the Moon
	7	Venus 4° south of the Moon
	8	Jupiter at opposition
	14	Aldebaran 0.3° south of the Moon
	20	Southern autumnal equinox
	21	Regulus 3° north of the Moon
	22	Jupiter 2° north of the Moon
	25	Spica 5° south of the Moon
	29	Mars 4° south of the Moon

Times are listed in Australian Eastern Standard Time



February 2016
Phases

Last Quarter	February 1, 03:28 UT
New Moon	February 9, 02:39 UT
First Quarter	February 15, 07:46 UT
Full Moon	February 22, 18:20 UT

Distances

Perigee	February 11, 03h UT 364,360 km
Apogee	February 27, 03h UT 405,383 km

March 2016
Phases

Last Quarter	March 1, 23:11 UT
New Moon	March 9, 01:54 UT
First Quarter	March 15, 17:03 UT
Full Moon	March 23, 12:01 UT

Distances

Perigee	March 10, 17h UT 359,510 km
Apogee	March 25, 14h UT 406,125 km

The Gamma Normids

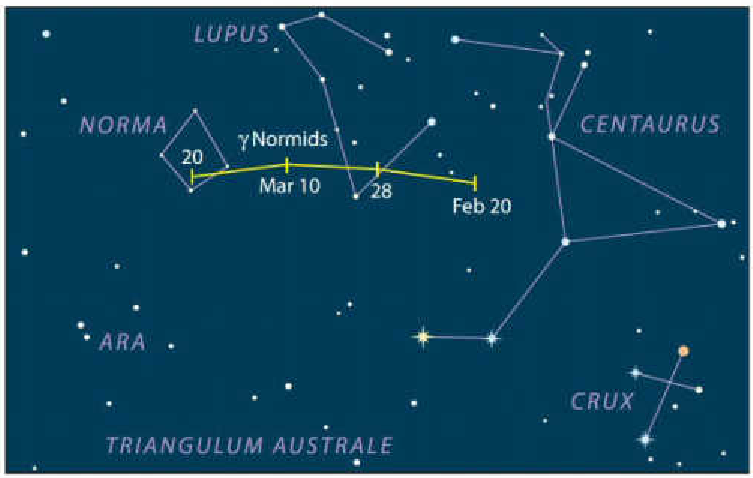
An easy shower of the deep southern sky. CON STOITSIS

For meteor shower observers, March is the time to catch some Gamma Normids. This shower was discovered by Ronald A. McIntosh (Auckland, New Zealand) in 1929, when its annual active period was initially thought to be March 7-12. It was virtually ignored until 1953, when radar equipment used by A. A. Weiss (University of Adelaide) accidentally detected some low activity on March 15-16. Not many observations were recorded in the 1960s and early 1970s, but the odd observation identified some activity around March 17-18.

Observers of the Western Australia Meteor Section (WAMS) have contributed greatly to observations of the shower. In 1979, the Gamma Normids were observed over the period of March 16-18. Maximum came on March 17, with a zenithal hourly rate (ZHR) of 7 to 8. The following year, observations were made during March 14-15 and a maximum was detected on March 15, with a ZHR 8 to 9.

Moving forward to the current time, for most of their active period (Feb 25 to March 28), the Gamma Normids will be indistinguishable from background sporadic meteors. In 2016, activity is expected to peak on the nights of March 15-16. It's recommended that you start observing at 11:00pm on the 15th.

Fortunately, the first quarter Moon will not interfere greatly with observations. Rates should be around 4 to 6 meteors per hour from a dark sky location, closer to 2 to 3 from city locations. This shower has in previous years produced fireball and bolide activity, so it's worth having a look at. ✦



The Gamma Normid meteor shower will be well-placed for observation deep in the southern sky.

Con Stoitsis is the director of the Astronomical Society of Victoria's comet and meteor sections.

Stellar sketches

Pictor, 'the Painter', contains plenty of double star 'art' for backyard scopes.

ROSS GOULD

The constellation Pictor, the Painter, is not a bright constellation, but it can easily be found because it is adjacent to Canopus, second-brightest star in the sky. Here are some doubles mostly from its southern portion.

In the 1820s, James Dunlop found some of the wide, easy doubles in this region, observing from his Parramatta home with a rather primitive 23-cm speculum-mirrored Newtonian. **DUN 18** (**Iota Pic**) is a beautiful bright easy 12″ pair, both stars 6th magnitude, and an excellent object for small telescopes. The pale yellow stars stand out in the sparse faint field. It is located 3 degrees WNW of Alpha Doradus (mag 3.3).

Nearly 3.5 degrees ESE of Beta Pic (mag 3.86) is the bright, well-separated pair **DUN 20** (**Theta Pictoris**). Three quarters of a century after Dunlop, Robert Innes, at the Cape Observatory in South Africa, using a 46-cm refractor, found that the brighter of Dunlop's two stars was itself a much closer double, **I 435**. The first measures of I 345 gave a separation of only 0.45″, which decreased to 0.1″ in the 1990s. Since then the pair has been widening, and will continue to do so until the 2040s. The calculated orbit, of period 123 years, is a preliminary attempt that we can expect to be modified in the future. Some past measures with modest apertures suggest the maximum separation is nearer 0.5″ than the 0.4″ predicted by the present orbit calculation.

Heading southwards and east, **Mu Pictoris** is some 4 degrees NW from 3.24-magnitude Alpha Pic. A bright white star with a 9th-magnitude companion close SW, the pair has shown no real change since discovery by John Herschel in 1836. Seen as a neat contrasting pair with 18 cm at 180×, Hartung optimistically suggests 7.5 cm can show it "with close attention".

Two degrees just south of west from Mu is **DUN 27**, another of the wide, bright pairs that show well through small telescopes. The stars are yellow and in a fairly starry field. This is an optical pair, and the different motions through space of the stars have brought them closer together than in Dunlop's time.

Further south, and 4.5 degrees west of Alpha Pic is the tight double **I 3**. Another long-period binary, where the change since discovery is not large, this one has widened over time but at 1.1″ is still fairly close. With an 18-cm refractor the yellow star was separated into a nearly equal pair at 180×; a fine object.

Just over a degree west and slightly north from Alpha Pic is **I 5**. Quite easy at discovery (1894) and in the first half of the 20th century, at over 2″ separation, after the 1960s it closed quickly to a minimum of less than 0.2″ around 2004. Now widening, in 2014 it was measured at 0.64″. A preliminary orbit of period 218 years has been calculated, and the ephemeris suggests ~0.75″ separation in early 2016. The brightness difference between the stars of 2.5 magnitudes makes it harder to observe. The Rayleigh Criterion is a good basis here for estimating resolution — 18 cm aperture fits for a Rayleigh split. Somewhat larger apertures, around 22 to 25 cm, will put the secondary star on the diffraction ring, making it harder to see; 30 cm will place the secondary star just outside the diffraction ring.

Between I 5 and Alpha Pic is the tight pair **I 6**, both stars near magnitude 8. Another of the early discoveries by Innes, it was around 1.0″ separation at the time, but by 1997 had closed to 0.65″. In 1997 I saw it as a kissing-discs double using 18 cm at 330×. It appears to be a binary in a large, long-period orbit, and like I 5 is seen nearly edge-on from Earth. There's no parallax measure for I 6, but based on the spectral classification I've estimated the distance as a bit over 200 light-years. ✦

The double stars of southern Pictor

Star Name	R. A.	Dec.	Magnitudes	Separation	Position Angle	Date of Measure	Spectrum
Iota (DUN 18)	$04^h\ 50.9^m$	-53° 28′	5.6, 6.2	12.8"	060	2009	F0IV, F4V
DUN 20	$05^h\ 24.8^m$	-52° 19′	AB,C 6.2, 6.7	38.3"	288	2008	A0V
I 345	"	"	AB 6.8, 7.4	0.32"*	206e*	2016	A0V+A2V
I 3	$06^h\ 12.5^m$	-61° 28′	7.1, 7.6	1.1"	350	2008	B9.5V
DUN 27	$06^h\ 16.3^m$	-59° 13′	6.5, 7.6	58.0"	233	1999	G0V+F8
Mu (HJ 3874)	$06^h\ 32.0^m$	-58° 45′	5.6, 9.3	2.5"	230	1991	B9Ve
I 5	$06^h\ 38.0^m$	-61° 32′	6.3, 8.8	0.64"	100	2014	G1-2V, K3
I 6	$06^h\ 42.5^m$	-61° 45′	7.7, 8.2	0.6"	257	1997	F5IV/V

Data from the *Washington Double Star Catalog*. * = *ephemeris preditions*

Ross Gould** has been a long-time observer from suburban Canberra. He can be reached at **rgould1792@optusnet.com

A rare visual find

The last non-electronically discovered comet will grace our evening skies.

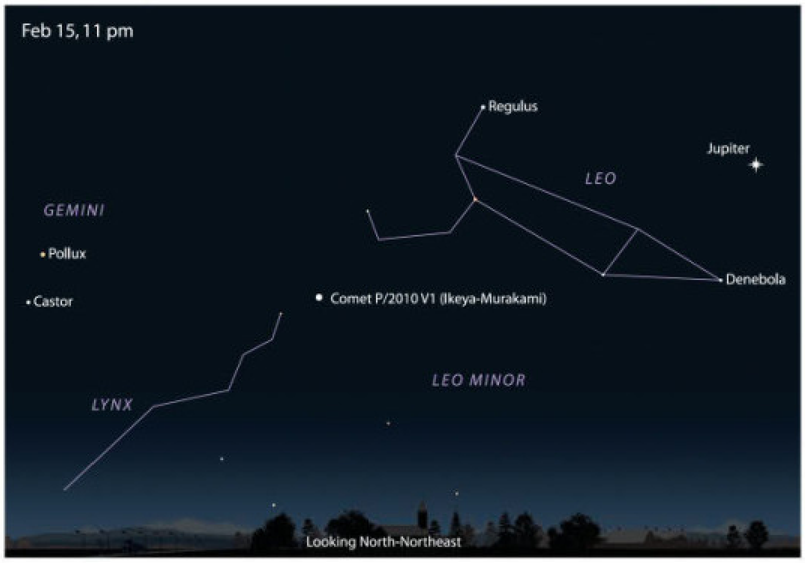
DAVID SEARGENT

Early February may witness yet another PANSTARRS comet coming into the range of small telescopes and large binoculars, albeit very low in the early evening skies as it moves southward through Pegasus and into Pisces before disappearing, for a time, into the evening twilight.

This is C/2013 X1 (PANSTARRS), discovered on December 4, 2013, as a 20.2-magnitude speck of light recorded by the Pan-STARRS 1 telescope at Haleakala. Apparently making its maiden voyage to the inner Solar System, the comet will reach perihelion, at 1.31 a.u., on April 20, and will become very well-placed for observers at mid-southern latitudes during June when it comes within 0.7 a.u. of Earth.

Early CCD estimates suggested that the comet was intrinsically faint and even at its peak brightness would probably do no better than magnitude 10 to 11. Nevertheless, visual observations last September found it considerably brighter than predicted at around magnitude 12 to 13. If this intrinsic brightness holds throughout the period of the comet's visibility, its magnitude in June should be in the 7 to 8 range, making it a good object for binoculars from the Southern Hemisphere.

It will therefore be interesting to see how bright it appears in early February. Given those visual estimates during September, and assuming the average rate of brightness increase for dynamically new comets, we would expect magnitude 10 or thereabouts at the beginning of the month. At this time the comet will be accessible in the early evening very low in the north-western sky, at least for observers at lower southern latitudes. A brightness of that order would be encouraging for the comet's mid-year prospects.



Comet P/2010 V1 (Ikeya-Murakami) could reach magnitude 9 in February and March. This is the view looking north at 11:00pm local time.

Another comet of possible interest is the short-period object P/2010 V1 (Ikeya-Murakami). This comet was discovered visually on November 3, 2010 by famed comet hunter Kaoru Ikeya (best known as the co-discoverer of the great sungrazer on 1965, which briefly became one of the most brilliant on record) and Shigeki Murakami. The comet appeared quite suddenly in the morning sky and was unquestionably in a state of outburst at the time. This, of course, makes brightness prediction for the 2016 return very uncertain but at least it explains why the comet had not been discovered earlier.

This year, Ikeya-Murakami will reach perihelion at 1.57 a.u. on March 10, after having reached its minimum distance from Earth (0.62 a.u.) on February 20.

The comet's visibility will depend upon whether it has returned to its base intrinsic brightness (whatever that might be!) or whether it retains something of the lustre attained in 2010. Was the comet weakly active on recent returns? Was the outburst of 2010 a one-off? Is this a previously dormant comet that awoke from hibernation in 2010 and will continue to be relatively active? This year's apparition should at least partially answer these questions.

The prediction published on the International Comet Quarterly (icq.eps.harvard.edu) website gives a maximum magnitude of 9 during February and March. This may well be too optimistic, although the comet may yet surprise us.

By the way, at the time of writing, this was the last comet discovered by the old-fashioned visual means. Let's hope that it will not also be the *final* one discovered in this way. ✦

David Seargent*'s book on comets, Snowballs in the Furnace, is available from* ***Amazon.com***

An easy observing project

RZ Velorum is the perfect target for a simple study that anyone can participate in.

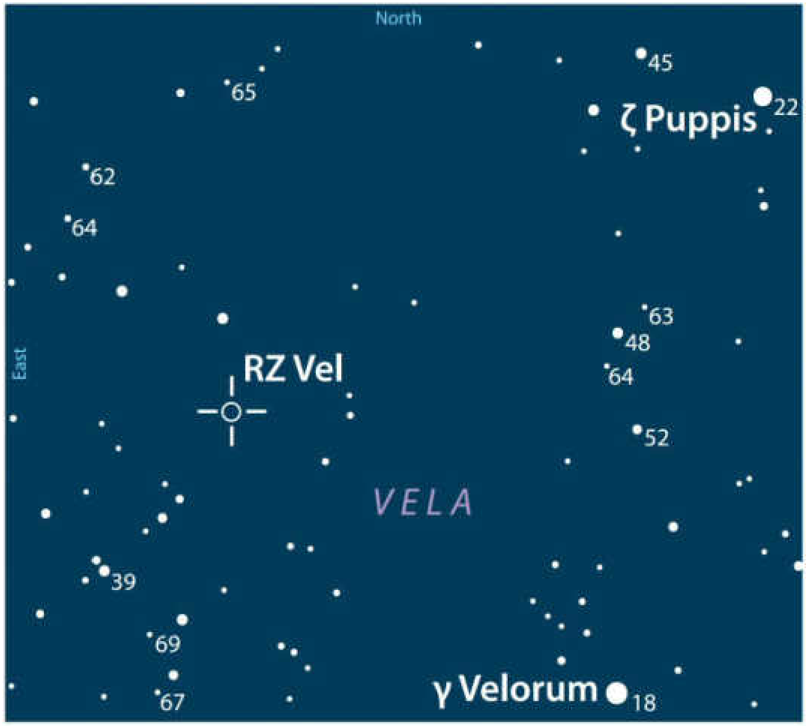
ALAN PLUMMER

Here's an idea for an easy science project in which everyone can participate — the observation of a stellar target that is scientifically useful, which undergoes an observable pulsation cycle over just a few weeks, and is within the range of binoculars or small telescopes from city skies. Cepheid-type variable stars fit the bill, and overhead now is RZ Velorum, this month's variable star target. It has a period of 20.4 days and a visual magnitude range of 6.42 to 7.64.

Cepheids are interesting and their study is valuable to astronomy. These stars' pulsation periods are related to their absolute brightness and mass, and can be used to work out how far away they are. By comparing current observations with historical records, any evolutionary changes become apparent. To do this well is a challenge, and observational collaborations are essential.

RZ Vel is one of a number of targets being studied by Stan Walker of the Variable Stars South (variablestarssouth.org) organisation, and your participation in the project will be welcomed. Help and mentoring, along with special charts, are all available through the VSS website (variablestarssouth.org). All that's needed is a brief learning period, then only one observation per night... and it doesn't matter if you miss a night or three because of the weather. Good luck! ✦

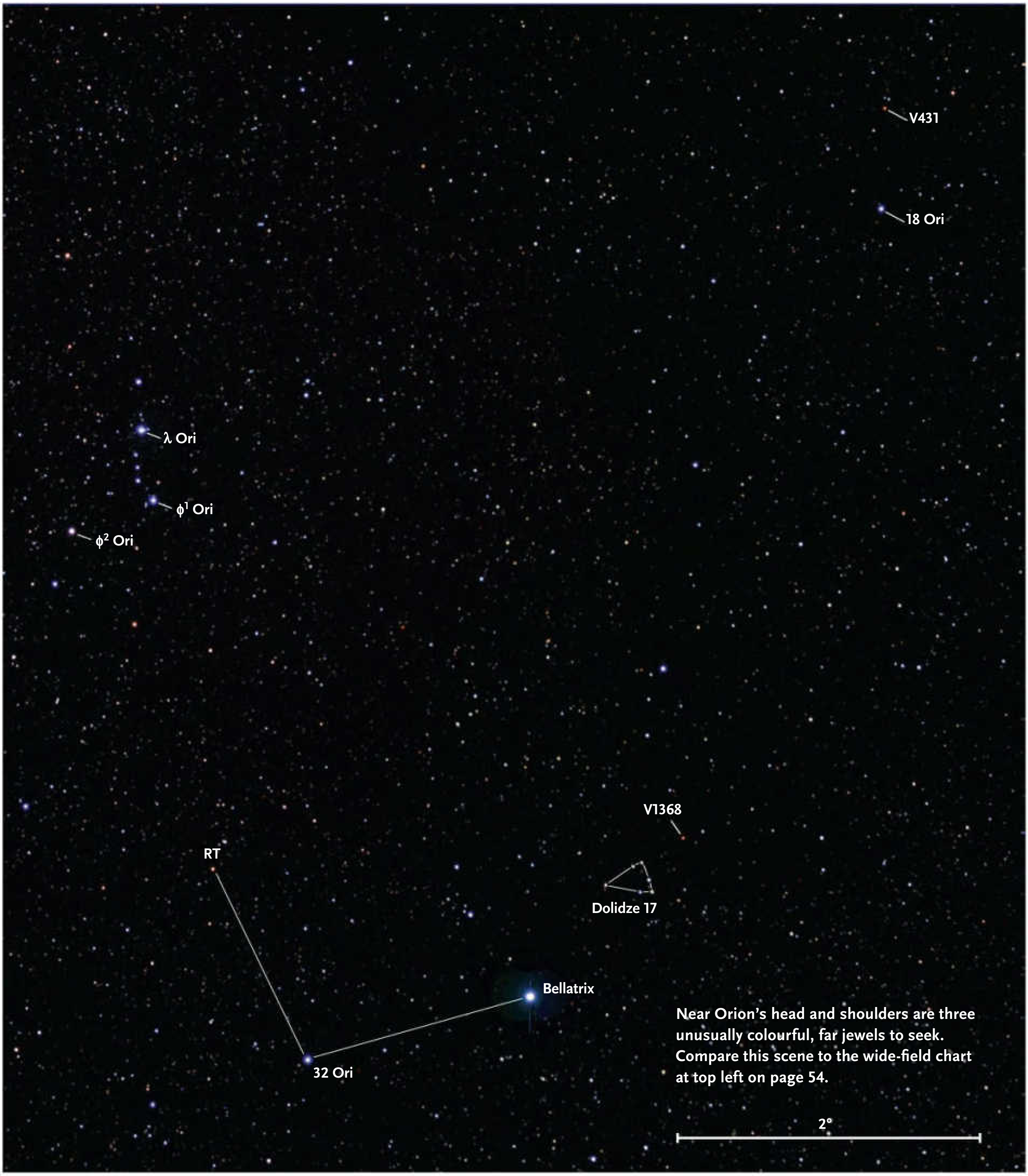
*Alan Plummer observes from the Blue Mountains west of Sydney, and can be contacted on **alan.plummer@variablestarssouth.org***



RZ Vel is located at 08h 37m 01.30s, –44° 06" 52.8" (epoch J2000). This chart comes courtesy of the AAVSO; north is up. For scale, Gamma Velorum and Zeta Puppis are eight degrees apart. Visual magnitudes are shown with decimal points omitted to avoid confusion with faint stars — so 65 denotes a 6.5-magnitude star.

Venus, the Moon and comet C/2013 US10 (Catalina) — the latter is the tiny, circular smudge near the bottom-left corner — gathered in the dawn sky on December 8. Photographer Stephen Mudge used a Canon 6D and 70-200mm telephoto lens, and stacked sixteen, 1.6-second exposures (3200 ISO).

Alan MacRobert
Observing Orion



Near Orion's head and shoulders are three unusually colourful, far jewels to seek. Compare this scene to the wide-field chart at top left on page 54.

DIGITIZED SKY SURVEY

Red stars rise in Orion

Betelgeuse is just the teaser. Dig up these very red carbon stars hiding high in its vicinity these summer nights.

The brightest 'red' star in the sky? Most of us know that's Betelgeuse in Orion's shoulder. Closely following Betelgeuse is Antares, which helps give Scorpius its title of 'the Orion of winter'. Both are type-*M2* supergiants about 500 or 600 light-years away.

But as you might know, *M* stars are not red but deep yellow-orange. Nearly all those we see are giants or supergiants; the brightest red dwarf in the sky is the little *M2* star Lalande 21185 in the hind feet of the Northern Hemisphere constellation, Ursa Major, and is a binocular or small-scope pickup at visual magnitude 7.5. Observed carefully through a 20-cm or larger scope, it's even less red than Betelgeuse or Antares. All dwarf stars are a bit less red than giants of the same spectral class; this is due to their compactness and, therefore, much stronger surface gravity. In strong gravity, a star's surface material is compressed and dense. That makes it show the same spectral lines as a slightly cooler and hence redder giant. A giant's visible surface is under such weak gravity and low pressure that it's practically a vacuum.

Carbon filters

But real red? No star is as red as a traffic light. But the reddest shades of orange can be found among the *carbon stars*: red giants (for the most part) that possess more carbon in their atmospheres than oxygen.

Most giants have more than enough oxygen to scavenge up all carbon and, at the temperatures and pressures in an *M* star's atmosphere, turn it into colourless carbon monoxide. But if carbon atoms outnumber oxygen atoms, some of the excess forms C_2 vapour, a red gas. So the star is overlayered with a red filter. Sometimes the excess carbon also forms fine particles of soot — star smoke — that further reddens the star, like the Sun seen through woodsmoke or heavy particulate pollution over a city.

Since Betelgeuse and Orion are so familiar, here are three carbon stars you probably didn't know about that lurk there, hiding in plain (telescopic) sight.

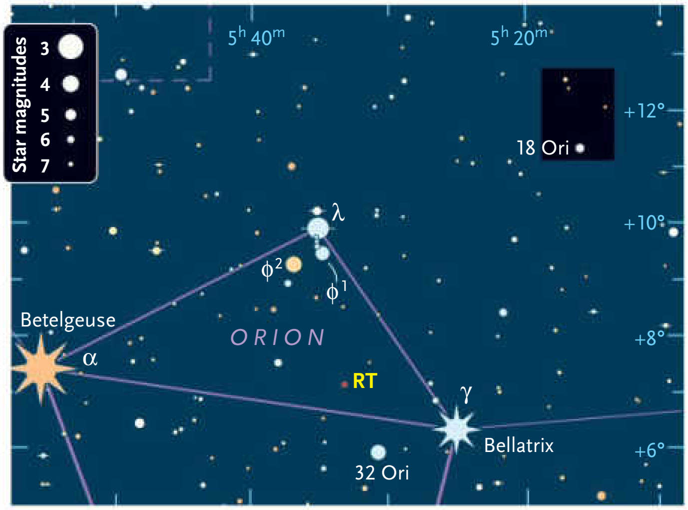
RT Orionis is an easy starter to find. It varies slowly and semiregularly between visual magnitude 8.0 and 8.9. It's a simple two-step star-hop starting from Bellatrix, Orion's dimmer shoulder, as shown on the photo. From Bellatrix go 1.5° east-southeast to hit 4th-magnitude 32 Orionis. From there swing 120° counterclockwise, go almost the same distance again, and you're on RT. Its colour helps give it away.

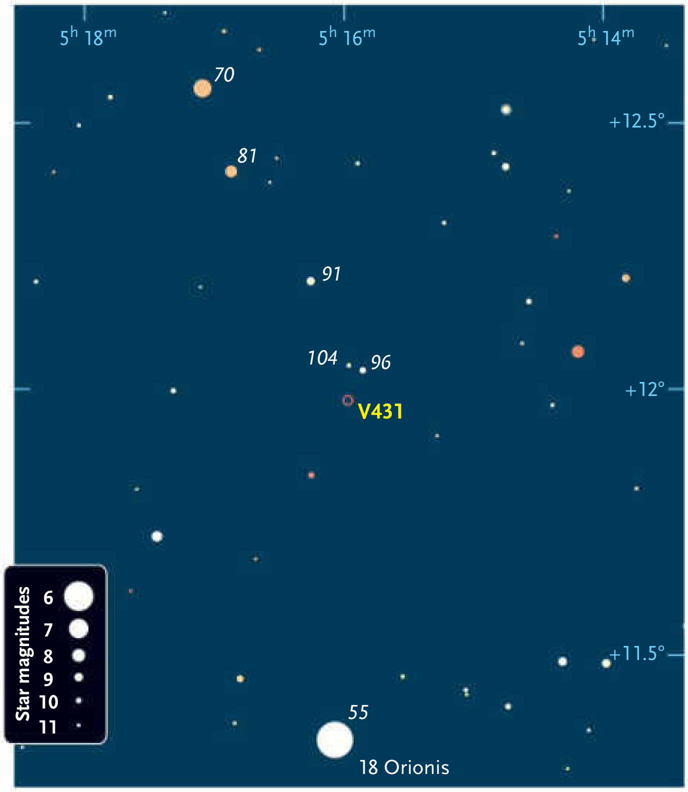
While you're at it, 32 Orionis is a special sight itself: a tight double star that will test your scope and the night's seeing. Its two components differ in brightness by a factor of four, at magnitudes 4.2 and 5.8, making them a tough split at their separation of just 1.3″.

On the other side of Bellatrix is V1368 Orionis, fainter at about magnitude 9.8 and only slightly variable. Jump from Bellatrix to the loose triangular cluster or asterism Dolidze 17, marked on the photo. Its six stars, 7th and 8th magnitude, form a distinctive symmetrical pattern 0.3° wide. From its north corner look another 0.3° northwest, and there you are. Again, the star's colour helps it stand out.

Farther off in the bleak wilderness is V431 Orionis. Start from Lambda (λ) Ori, Orion's little 3rd-magnitude head. Use the wide-field chart to step 5° west-northwest to

Observing Orion





For all its familiarity, Orion hides the red carbon stars RT, V1368 and V431 Orionis in its lower portions. They're all findable with a 75-cm scope. On the wide-field chart above, the black box shows the area of the closeup below you'll need for V431. On the closeup at right, italic numbers are visual magnitudes of comparison stars with the decimal point omitted.

18 Orionis, magnitude 5.5. That gets you into the area of the close-up chart. V431 is 0.6° due north from 18 Ori. It varies more than the others but spends most of its time between magnitudes 9 and 11.

The close-up chart gives comparison-star magnitudes for estimating its brightness. But with a target so different in colour from the stars around it, visual magnitude estimates are notoriously unreliable. For one thing, our eye lenses yellow with age! Older folks see the world through yellow filters. This means they systematically estimate reddish stars brighter compared to white ones than young people do.

Interested in pursuing carbon stars further? Bob King lists a dozen of the brightest, with descriptions, at 'Carbon Stars Will Make You See Red': **http://is.gd/kingcarbonstars**. One of these is BL Orionis, visual magnitude 6.0 to 7.0, off to the east of Orion's Club on the border of Gemini.

The Astronomical League runs a Carbon Star Observing Program, at **http://is.gd/alcarbonstars**. There you'll find instructions and a carefully chosen table of 100 of these rubies all over the sky. ✦

Jupiter in January and February

Jupiter comes to opposition on March 8th. So in February it's already high before midnight, and at 43″ to 44″ across its equator it's about as big as it will appear this year.

Any telescope shows Jupiter's four big Galilean moons. Binoculars almost always show at least two or three. Identify them using the diagram at far left.

All the February interactions between Jupiter and its satellites and their shadows are tabulated below.

Here are the times, in Universal Time, when Jupiter's Great Red Spot should cross the planet's central meridian. The dates, also in UT, are in bold.

January 15, 5:29, 15:24; **16**, 1:20, 11:15, 21:11; **17**, 7:07, 17:02; **18**, 2:58, 12:53, 22:49; **19**, 8:45, 18:40; **20**, 4:36, 14:31; **21**, 0:27, 10:23, 20:18; **22**, 6:14, 16:09; **23**, 2:05, 12:01, 21:56; **24**, 7:52, 17:47; **25**, 3:43, 13:39, 23:34; **26**, 9:30, 19:25; **27**, 5:21, 15:17; **28**, 1:12, 11:08, 21:03; **29**, 6:59, 16:55; **30**, 2:50, 12:46, 22:41; **31**, 8:37, 18:33.

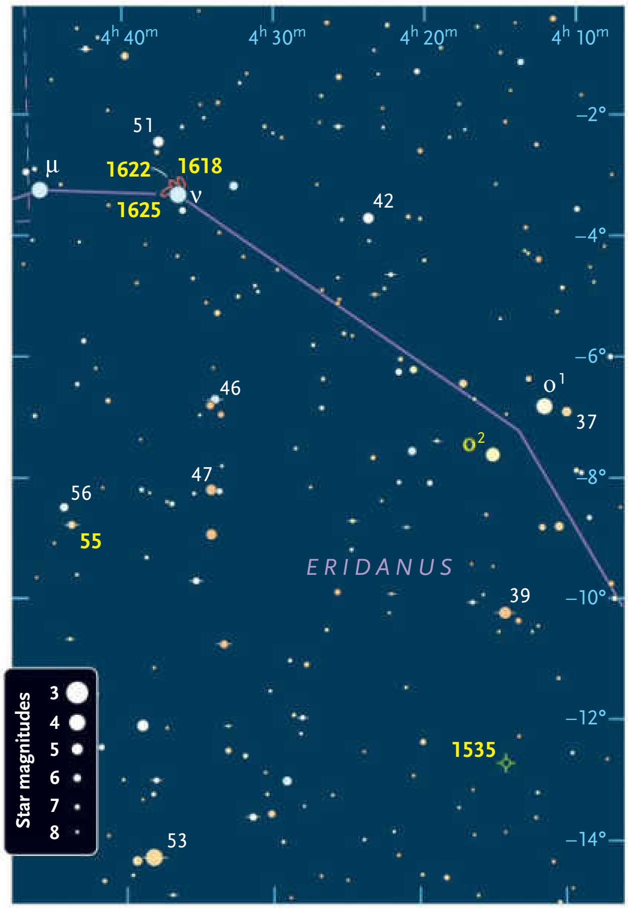
February 1, 4:28, 14:24; **2**, 0:19, 10:15, 20:11; **3**, 6:06, 16:02; **4**, 1:57, 11:53, 21:48; **5**, 7:44, 17:40; **6**, 3:35, 13:31, 23:26; **7**, 9:22, 19:18; **8**, 5:13, 15:09; **9**, 1:04, 11:00, 20:56; **10**, 6:51, 16:47; **11**, 2:42, 12:38, 22:33; **12**, 8:29, 18:25; **13**, 4:20, 14:16; **14**, 0:11, 10:07, 20:02; **15**, 5:58, 15:54; **16**, 1:49, 11:45, 21:40; **17**, 7:36, 17:32; **18**, 3:27, 13:23, 23:18; **19**, 9:14, 19:09; **20**, 5:05, 15:01; **21**, 0:56, 10:52, 20:47; **22**, 6:43, 16:38; **23**, 2:34, 12:30, 22:25; **24**, 8:21, 18:16; **25**, 4:12, 14:08; **26**, 0:03, 9:59, 19:54; **27**, 5:50, 15:45; **28**, 1:41, 11:37, 21:32; **29**, 7:28, 17:23. ✦

Take me to the River

Explore the reaches of the ancient celestial waterway, Eridanus.

The long and winding constellation Eridanus, the River, begins west of brilliant Rigel, meandering southward in great loops into the southern sky. The river is mythologically tied to Phaethon, the mortal son of Helios, who tried to drive the Sun across the sky in his father's chariot. Phaethon couldn't manage the fiery steeds that pulled the chariot, nor the fierce beasts such as Taurus and Leo that dwelt in the sky. The horses ran wild, soaring high into the heavens and endangering the palaces of the gods, then plunged close to the ground, setting the Earth afire. To end this disastrous ride, Zeus loosed a thunderbolt at the chariot. Ill-fated Phaethon plummeted from the sky, his charred remains falling into the river Eridanus.

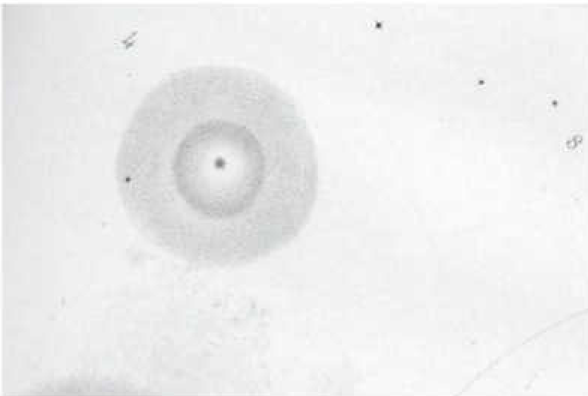
Let's begin our river ride with the beautiful and intriguing triple star system Omicron^2 (o^2) Eridani, located 15° west of Rigel. (As a handy measure, spread your index finger and pinky finger as far apart as possible. If you hold them at arm's length, they'll span about 15° of sky.) Through my 130-mm refractor at 23×, the lovely golden primary star watches over a much dimmer companion a spacious 1.4′ to its east-southeast. The companion star is separated into two components when I up the magnification to 63×, although I need to use higher powers when the seeing (atmospheric steadiness) is poor. The brighter star appears white, while the fainter one only 9″ to its north-northwest is, well, not white. It's simply too dim



POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

The elongated, nearly edge-on spiral galaxies NGC 1618, NGC 1622 and NGC 1625 form a tiara above the brighter jewel Nu Eridani.

ADAM BLOCK / NOAO / AURA / NSF



MEMOIRS OF THE ROYAL ASTRONOMICAL SOCIETY

After observing NGC 1535 on multiple evenings in the winter of 1862 with a 120-cm reflector, William Lassell described it as "a very remarkable Planetary Nebula," with a nucleus that didn't "seem stellar, but a small patch of bright light."

for me to determine the colour. However, my 25-cm scope reveals a smouldering reddish ember.

The snowy companion is a white dwarf star, the easiest one to view through a small telescope. It's only 16.2 light-years away from us and separated from its primary by at least 400 times the Earth-Sun distance, a combination that keeps the dwarf well out of the primary's glare from our vantage point on Earth. This petite star is only 1½ times the diameter of the Earth, yet it weighs in at half the mass of the Sun. A white dwarf is the collapsed core of a low- to intermediate-mass star that shed much of its substance during the late stages of its life. No longer generating heat, a white dwarf will cool until it becomes a 'black dwarf'. This process takes such an incredibly long time that our universe isn't yet old enough to contain any black dwarf stars.

The ruddy companion is a red dwarf star merely one-fifth the mass of our Sun. The red dwarf and the system's primary are both main-sequence stars, still fusing hydrogen into helium in their cores. Since high-mass stars have shorter main-sequence lives than low mass stars, the burned-out white dwarf must once have been the trinary's brightest and most massive star.

The golden primary star holds a pop-culture claim to fame. In the world of science fiction, it's the star that the planet Vulcan orbits in the television and movie universe of *Star Trek*.

South of Omicron^2 you'll find yellow-orange 39 Eridani, and if you drop the same distance southward again, you'll come to a splendid planetary nebula, NGC 1535. It bears the captivating nickname Cleopatra's Eye, coined by amateur/professional astronomer Greg Crinklaw. Let's see why.

Cleopatra's Eye announces its presence in the form of a tiny, bluish disk through my 130-mm scope at 23×. At 164× it shows a fairly bright central star in a bright, slightly oval (northeast-southwest) ring that's nested in a wide, modestly bright, outer halo. The nebula is very pretty at 234×. Its central star is plainly visible, and its ring has an ashen, blue-green cast. The ring's outer border is well-defined, but its inner edge is rather indistinct. I estimate the nebula's dimensions as roughly ¾′ × ⅔′. Switching to my 25-cm reflector at 220×, the hollow surrounding the central star doesn't seem to be a uniform, round hole so much as a region mottled with darker patches. Can you imagine Cleopatra's blue and green eye shadow and the seductive star-twinkle in her eye?

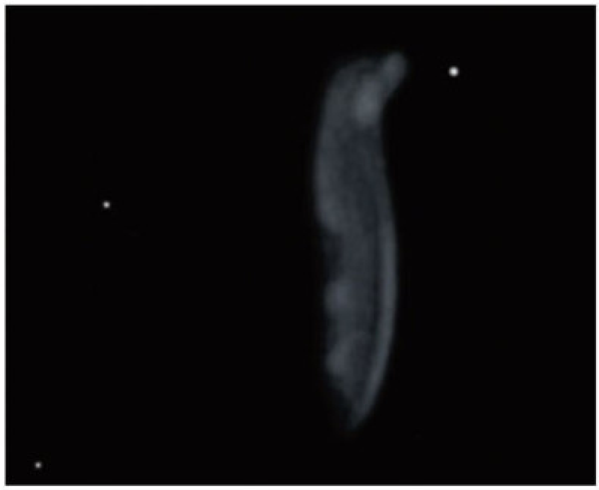
Swimming in the Celestial Stream

Angular sizes and separations are from recent catalogues. Visually, an object's size is often smaller than the catalogued value and varies according to the aperture and magnification of the viewing instrument. Right ascension and declination are for equinox 2000.0.

Object	Type	Mag(v)	Size/Sep	RA	Dec.
o^2 Eri	Triple star	4.5, 10.0, 11.5	82″ (A, BC), 9.0″ (BC)	04^h 15.3^m	–07° 39′
NGC 1535	Planetary nebula	9.6	48″ × 42″	04^h 14.3^m	–12° 44′
NGC 1618	Spiral galaxy	12.7	2.3′ × 0.8′	04^h 36.1^m	–03° 09′
NGC 1622	Spiral galaxy	12.5	3.6′ × 0.7′	04^h 46.6^m	–03° 11′
NGC 1625	Spiral galaxy	12.3	2.1′ × 0.5′	04^h 37.1^m	–03° 18′
55 Eri	Double star	6.7, 6.8	9.3″	04^h 43.6^m	–08° 48′
NGC 1421	Spiral galaxy	11.4	3.5′ × 0.9′	03^h 42.5^m	–13° 29′

POSS-II / STSCI / CALTECH / PALOMAR OBSERVATORY

NGC 1421 is seen almost edge-on from our vantage point, making it difficult to discern the (possible) central bar. Large apertures may reveal primary or secondary arms.



BERTRAND LAVILLE

Through the eyepiece, NGC 1421 appears as a subtle celestial slug, elongated north-south. Look for the 12th-magnitude star west of the distortion characterising the galaxy's north end.

The renowned British observer William Herschel discovered NGC 1535 with his 47.5-cm (18.7-inch) reflector on the night of February 1, 1785. His log reads, "A very curious planetary. Very bright, of a uniform brightness all but the edges, which are ill defined; about half a minute in diameter . . . perfectly round or perhaps a very little elliptical". In 1862 William Lassell sketched NGC 1535 as seen through his 120-cm reflector and called it "An extraordinary and beautiful Planetary Nebula". Both observers used telescopes with speculum-metal mirrors, which were considerably less reflective than today's aluminium-on-glass mirrors.

NGC 1618, NGC 1622 and NGC 1625 gather near dazzling Nu (ν) Eridani like moths to a flame. All three are spiral galaxies whose disks are seen nearly edge on, so they appear quite slender in our sky. This amazing array is certainly visible at 117× through my 130-mm refractor, but the 25-cm scope at 90× gives a more compelling view. NGC 1625 appears fairly bright and intensifies considerably toward the centre. NGC 1622 is longer but has faint extremities, and NGC 1618 looks shorter with less difference in brightness between its centre and tips.

Despite their proximity in the sky, these galaxies were each discovered by a different observer. NGC 1618 was found first, by William Herschel exactly one year to the day after discovering NGC 1535. His son, John Herschel, turned up NGC 1625 some 41 years later. Another 23 years would pass before George Johnstone Stoney, working in Ireland under Lord Rosse, discovered NGC 1622 with the great 180-cm (72-inch) 'Leviathan' of Parsonstown. This unusual galaxy trio dwells about 200 million light-years away from us.

Sitting 6° degrees south-southeast of the galaxy triplet, 55 Eridani is a delightful double star. My 130-mm scope at 23× reveals tightly spaced stars with almost equal magnitudes. They're quite striking at 63×. The slightly brighter star glows buttercup yellow, while its companion to northeast shines with the hue of a pale yellow primrose.

The distance to 55 Eridani is poorly known. According to the Extended Hipparcos Compilation (XHIP), it has a 68% probability of being somewhere between 323 and 460 light-years.

William Herschel discovered NGC 1421 on the same night as NGC 1535. This edge-on spiral galaxy rests 1.6° south-southwest of reddish orange Pi (π) Eridani. Equipped with a wide-angle eyepiece, my 130-mm refractor at 63× shows a nice little north-south slash of light off the southwestern side of a ½° circlet of fairly bright stars. It presents a slim 3′ × ½′ profile and has a 12th-magnitude star 3′ west of its northern tip. Through my 25-cm reflector at 118×, NGC 1421 displays an odd brightness pattern, rather like a dark lane but more irregular. A magnification of 220× gives a very nice view of this interplay of light and dark, as well as a bright patch on the western side of the galaxy's northern tip.

NGC 1421 is about 84 million light-years distant, much closer to us than the galaxy trio discussed above. In their book *The de Vaucouleurs Atlas of Galaxies*, Ronald Buta, Harold Corwin and Stephen Odewahn write that NGC 1421's features imply a galaxy with a highly foreshortened bar, or perhaps one that has undergone some type of interaction. Galaxies may become highly dishevelled due to tidal interactions or mergers with other galaxies. In a 2005 paper in *Astronomy & Astrophysics*, Frédéric Bournaud and colleagues suggest that this also occurs when galaxies accrete gas from over-dense filaments that thread our universe. The amount of gas accumulated over a few billion years can be a significant fraction of the mass of a galaxy's entire disk. The galaxy becomes visibly distorted if the gas accretes asymmetrically and triggers star formation. This could help explain the frequency of strongly lopsided disks among isolated galaxies such as NGC 1421. ✦

Charles A. Wood
Exploring the Moon

A new angle on Crisium

How did the distinct oval on the Moon's eastern limb come to exist?

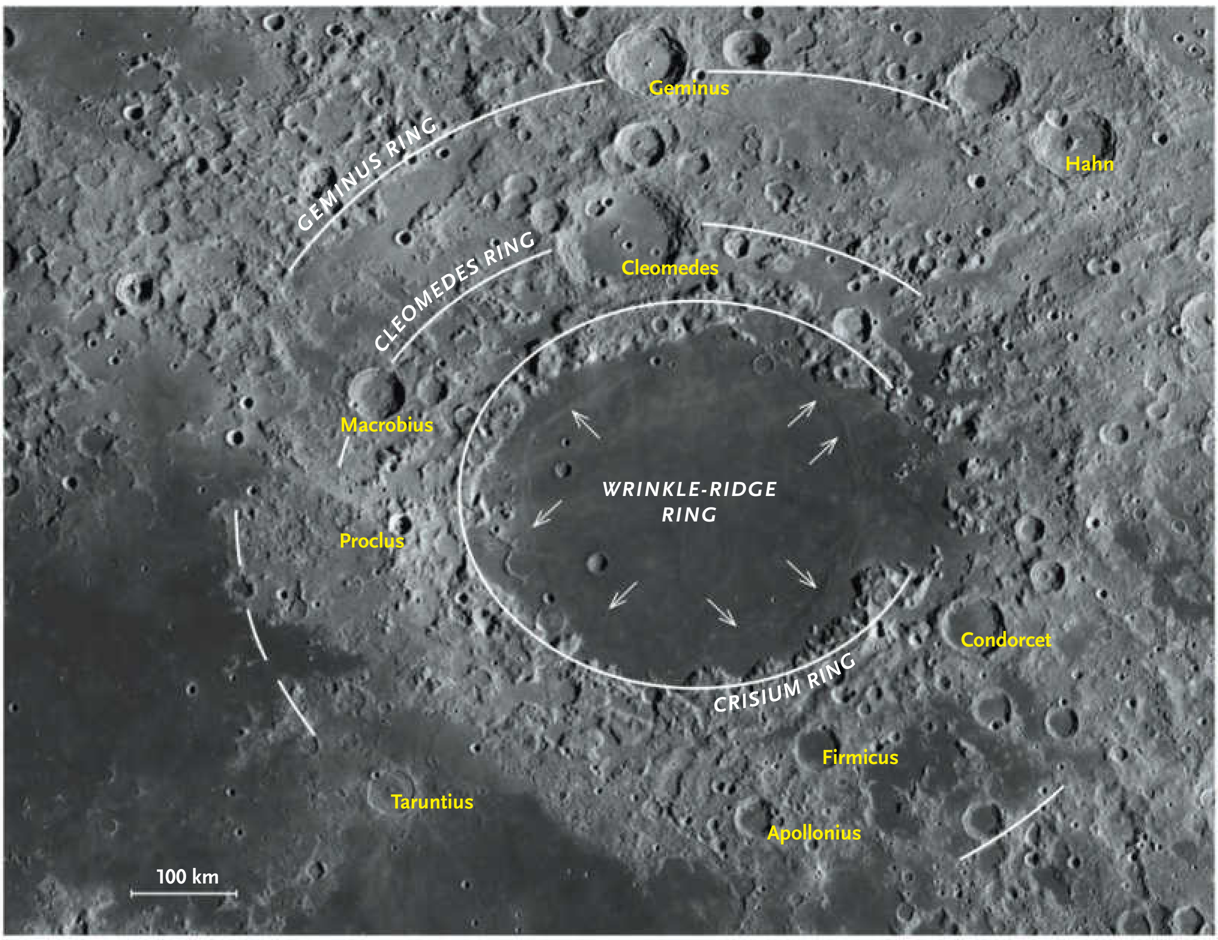
In the decades before we accepted the impact origin of lunar craters, some researchers interpreted their circular shapes as a telling argument *against* impacts. Why so? Since incoming projectiles almost certainly come from all directions, they reasoned, some craters should have *elliptical* shapes. The error of this reasoning is that the energy of impacts is so great that they're effectively point-source explosions, and these produce circular craters.

But many impacts must occur from projectiles coming in obliquely — in fact, 45° should be the most common impact angle. In order to investigate how these oblique impacts affect crater shapes, Apollo-era scientists conducted a set of experiments at a special facility at NASA's Ames Research Center in California. Using a 'vertical gun' that could shoot small projectiles extremely fast — up to 7 kilometres per second — the experiments could duplicate the collision of a cosmic fragment with the Moon.

The researchers found that even at impact angles of 30° to 40° above horizontal, the high-energy impacts made circular craters. However, at impact angles shallower than about 25°, the resulting crater was still circular — but its ejecta did not spread evenly all around. Instead, it became concentrated in the downrange direction. The most characteristic feature was a 'zone of avoidance' — an area with no rays — in the direction from which the projectile came.

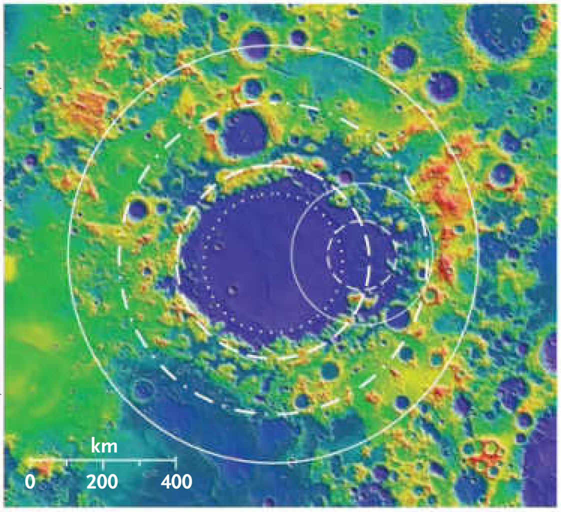
Proclus is the most conspicuous example of a lunar crater formed by an oblique impact, and the zone of avoidance in its rays clearly shows during full Moon.

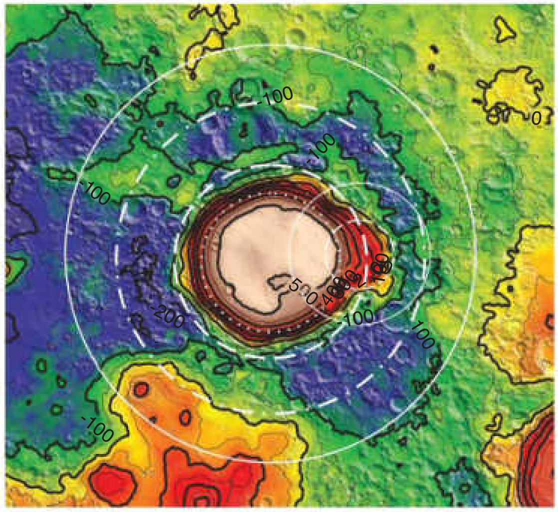
If some craters formed by projectiles striking



NASA / LUNAR RECONNAISSANCE ORBITER

Mare Crisium, situated near the Moon's eastern limb, has a distinctly elongated shape. Lunar geologists have identified several segments of the original basin's multiple rings.





SCIENCE ADVANCES / G. NEUMANN *ET AL.* (LEFT: NASA / LRO; RIGHT: NASA / GRAIL)

Concentric white circles identify the proposed basin rings of Crisium and the proposed 'Crisium East' to its immediate right. The left map depicts elevation (red is 7 km higher than the darkest blue), and the right map shows gravity enhancements (red and white indicate buried mass concentrations).

obliquely, then some giant impact basins probably did as well. In 1992 Robert Wichman and Peter Schultz (Brown University) proposed that a projectile coming from relatively low in the west excavated the Crisium basin. But it happened so far in the past, before about 3.9 billion years ago, that not enough ejecta remains recognisable today to define a zone of avoidance.

Instead, Wichman and Schultz noticed that Mare Crisium, when looked at from above, has an oval shape. The lava plains filling the basin stretch about 575 km from east to west but only about 430 km from north to south. They concluded that the projectile likely struck at a low enough angle to elongate the basin in the east-west direction.

This has been the generally accepted notion for more than 20 years, but new data from NASA's Gravity Recovery and Interior Laboratory (GRAIL) spacecraft offer an alternative interpretation. Scientists led by Gregory Neumann (NASA Goddard Space Flight Center) propose that Crisium resulted from *two* impact events. They base this interpretation on the discovery that, for well-defined impact basins, the inner basin ring — often defined by a concentric pattern of mare ridges — is commonly the same diameter as a gravitational 'high' created by a mass concentration (or *mascon*) beneath the basin's centre. Moreover, earlier studies showed that the main basin has roughly twice the diameter of this inner ring.

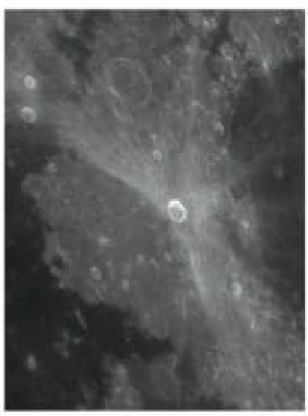
If all this is true, Crisium's central mascon defines a circular basin with a diameter of about 1,080 km. Its low, scarp-like rim is observable east and west of Geminus crater.

Neumann and his team interpret an extension of the mascon to the far eastern side of Mare Crisium as the gravity signature of a second, smaller basin with a diameter of 370 km that they dub 'Crisium East'. This proposed basin has no visible ring structures, but it accounts for the gap in the massive mountains that confine Crisium's mare flows everywhere except on the far eastern margin.

So lunar scientists now have two conflicting explanations for the elongation of Crisium: one oblique impact or two near-vertical impacts. You can conduct your own inquiry by using the QuickMap interactive mosaic (**http://is.gd/smi00w**) of Lunar Reconnaissance Orbiter images. Or use your own telescopic images, taken with different librations and angles of illumination, to search for the rings of the Crisium and putative Crisium East basins. You can use Photoshop to merge and reproject those images into the overhead perspective needed to recognise the true shapes.

Whichever interpretation ends up being correct, the Crisium region is rich both visually and scientifically. ✦

"Proclus is the most conspicuous example of a lunar crater formed by an oblique impact."



BOB PILZ

Just to Mare Crisium's west is Proclus, a fresh, 27-km-wide crater. The obvious gap in its rays implies that the impacting object came in at a low angle from the west (lower left).

Monsters

Despite their size, there's no need to fear giant elliptical and cD galaxies.

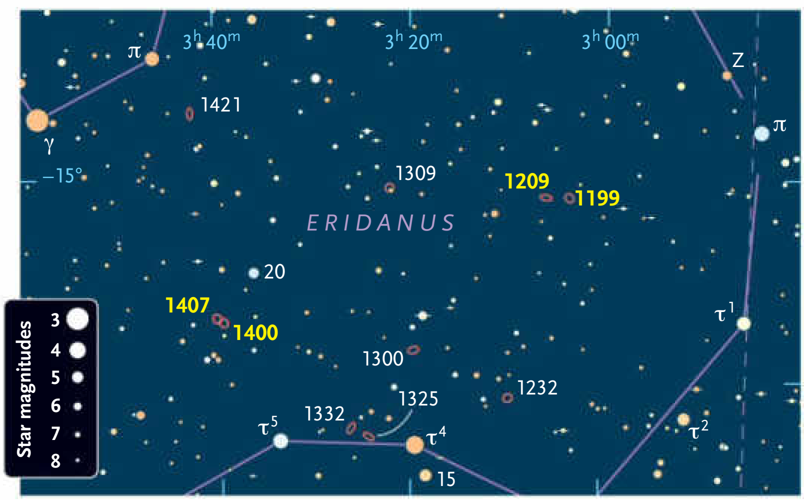
in the Dark

RICHARD JAKIEL

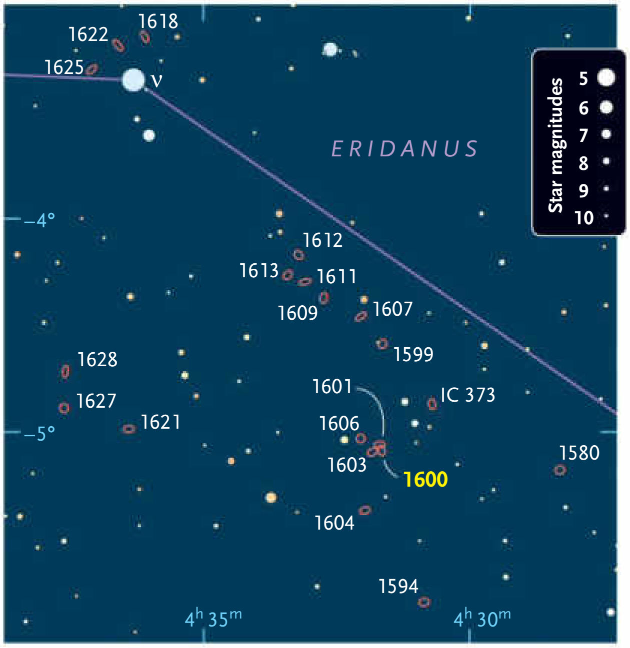
GIANT ELLIPTICALS and their close cousins, the supergiant cD ("central diffuse") galaxies, are the most massive and luminous galaxies in the universe. Their sheer size can dominate a galaxy cluster's evolution and dynamics. In general, these galaxies have a relatively high surface brightness, making them prime targets even for observers who live in areas suffering from urban light pollution. Though perhaps not as photogenic as spirals, giant ellipticals offer a challenge, both visual and intellectual, to observers at the eyepiece or camera.

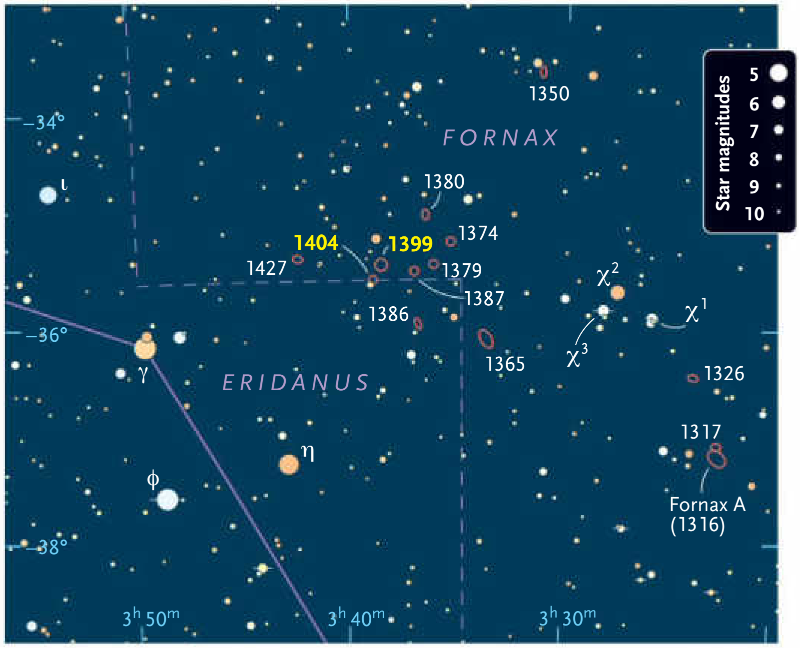
In Edwin Hubble's original 'tuning fork' scheme of galaxy classification (1926), ellipticals were thought of as simple systems and classified according to shape from spherical (E0) to a highly flattened ellipse (E7). However, many of these galaxies may be triaxial, like Aussie Rules' footballs instead of well-defined ellipses, depending on the dynamics of their stellar populations. Most of these gigantic systems are thought to be the end result of galactic mergers. Using CCDs to map the isophotes (ie. contour lines of equal brightness) of these galaxies has revealed some interesting structures. Those with a well-defined internal rotation have 'disky' isophotes, while those with motions resembling a random swarm of bees have 'boxy' isophote profiles. Throw in huge arc-like shells, supermassive black holes, powerful jets and cannibalism on a galactic scale, and the picture changes radically. Once considered to be huge, static balls of ancient stars with little ongoing star formation, these giant galaxies are really highly dynamic systems that control the evolution of large clusters of galaxies.

The numerous galaxy groups and clusters associated with Eridanus make an excellent starting point for observing these systems. Let's begin with **NGC 1407**, an E0 giant that dominates the core of a small galaxy group located approximately 92 million light-years from Earth. NGC 1407 is a huge spheroid of ancient stars, around 50,000 light-years in diameter, with a mass approaching a trillion Suns. In the galaxy's core lurks a black hole with a mass estimated at 1.03 billion solar masses. Nearby is **NGC 1400**, a slightly smaller E1/S0 system. Though these galaxies are in a sparse star field, star-hopping to them isn't difficult. I find it easiest to start at Tau^5 (19 Eridani), and move the scope about 2° to the northeast, until I see a nice triangle of 7th-magnitude stars through the finder scope. From there, it's a 45′ jaunt due north in the eyepiece. Visually, the galaxies make an



BOB FRANKE





interesting pair. NGC 1407 appears as a fairly bright, round 10th-magnitude haze about 4′ across with a dense, stellar core. NGC 1400 shines a bit fainter as an 11th-magnitude, slightly oval spot about 12′ southwest of NGC 1407. With a larger scope and/or darker skies, a number of other fainter systems in this cluster also become viable observing targets.

NGC 1199 is the brightest member of Hickson Compact Group (HCG) 22, located about 2° northeast of Tau[1] (1 Eridani). To get there, it's easiest to follow a nice dipper-like asterism of 7th-magnitude stars. Just off the end of the dipper are HCG 22 and NGC 1199. Classified as an E3, this galaxy's degree of flattening is a bit more noticeable than with NGC 1400 or NGC 1407. Through my 33-cm Dobsonian, NGC 1199 appears as an oval measuring 2′ × 1.5′ with a bright core, orientated roughly northeast-southwest. Make sure to check out the other fainter cluster members as well. About 35′ to the east of NGC 1199 lies **NGC 1209**, a strongly elongated E6 galaxy. It's been described as 'disky,' as images reveal a hint of an equatorial disk. Through my 28-cm Schmidt-Cassegrain at 155×, it appears as a moderately faint 1.5′ × 1′ oval haze oriented east-west.

A classic example of a 'boxy' elliptical lies in the northeast corner of Eridanus, near the Orion border, about 2° southwest of Nu (ν) Eridani. A nice chain of 6th- to 8th-magnitude stars leads from Nu to **NGC 1600**, an impressive system even for one of these monsters. Though at a distance of about 209 million light-years, this trillion-solar-mass E3-E4 galaxy shines at magnitude 10.9 and is at least 3 magnitudes brighter than the surrounding galaxies. Visually, it's a 2′ × 1.5′ oval orientated nearly north-south, with a moderately concentrated core and surrounded by several much fainter systems.

Outsize ellipticals such as NGC 1600 are extremely rare and generally are found in the cores of rich galaxy clusters. These massive supergiants are sometimes called cD (for 'central diffuse') galaxies as they are often embedded in faint, diffuse halos than can exceed a million light-years in radius. These giants are thought to be the product of 'galactic cannibalism,' a gravitational merger between two or more galaxies. Many of the resultant galaxies sport multiple nuclei, vast numbers of globular clusters and other physical remnants of these violent encounters.

For example, in the core of the Fornax Galaxy Cluster lies a spectacular pair of giant ellipticals, **NGC 1399** and **NGC 1404**. Finding this pair of galaxies isn't difficult: first locate the bright triangle of stars — g, f, and h Eridani — then sweep about 2° west from the northernmost star (g). NGC 1399 is a classic cD galaxy, displaying a huge diffuse halo with upwards of 7,000 globular clusters in orbit. It's the second brightest galaxy in the cluster at magnitude 9.6. Slightly smaller and dimmer NGC 1404 lies a mere 8′ to the southeast. Through my 33-cm scope at 150×, both appear as bright, round, diffuse spots about 3′ across with condensed cores. NGC 1399 also shows a faint field star just north of the nucleus, leading to the impression of a 'supernova' or double nuclei.

As we move toward autumn in the Southern Hemisphere, make plans to expand your observations to include the Coma and Virgo galaxy clusters. The core of the Coma Cluster (Abell 1656) harbours two massive ellipticals — **NGC 4874** and **NGC 4889**

— supergiant galaxies that have long dominated the cluster's evolution. The view here is particularly striking through a large scope, showing dozens of smaller systems surrounding these central giants. To star-hop to the core region, locate 4th-magnitude Beta Coma Berenici then sweep 2° due west.

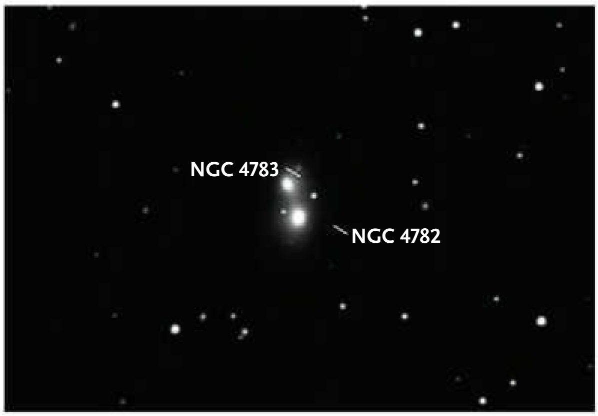
Perhaps the most famous supergiant elliptical galaxy of all is **M87**, lying near the centre of the Virgo Cluster. One of the largest galaxies in the universe, it dwarfs our Milky Way in every respect. By the numbers, it's a huge spheroid approximately 130,000 light-years across, tipping the scales at *2.7 trillion Suns* by some estimates, with over 12,000 globular clusters in orbit. But its most amazing feature is the relativistic jet of gas and dust being ejected from the (at least) 3 billion-solar-mass black hole at its core. First detected by Heber Curtis of Lick Observatory in 1918, the ray was reportedly observed visually by Otto Struve using the 100-inch telescope at Mount Wilson. A practiced observer — under excellent conditions — can detect the jet with a 38-cm or larger scope at high magnification. Through a 60-cm scope at 457×, it looks like a low-contrast 'spike' less than 20″ long trending slightly north of west.

Interacting galaxies **NGC 4782** and **NGC 4783** comprise a very unusual giant elliptical system located about 6° west of Spica, near the Corvus–Virgo border. Together, they're the brightest member(s) of the very rare class of co-rotating giant elliptical galaxies (similar systems include NGC 545 and NGC 547, and NGC 750 and NGC 751). Through the eyepiece of my 43-cm scope at 150×, the duo presents as a distinctly dumbbell-shaped object, the galaxies' outer halos partially merged.

Much farther to the south is the closest and brightest giant radio galaxy, **NGC 5128**, also called Centaurus A. Discovered in 1826 by James Dunlop, it's the 5th-brightest galaxy in the sky. Just like M87, it harbours a gigantic black hole at its core from which vast relativistic jets of dust and gas are ejected. A trillion-solar-mass monster, it's been devouring a smaller spiral galaxy over the past several hundred million years. Its unusual appearance is evident even through small telescopes. Through large instruments the view is stunning, showing a huge, intricate dust band cutting diagonally across the bright oval disk.

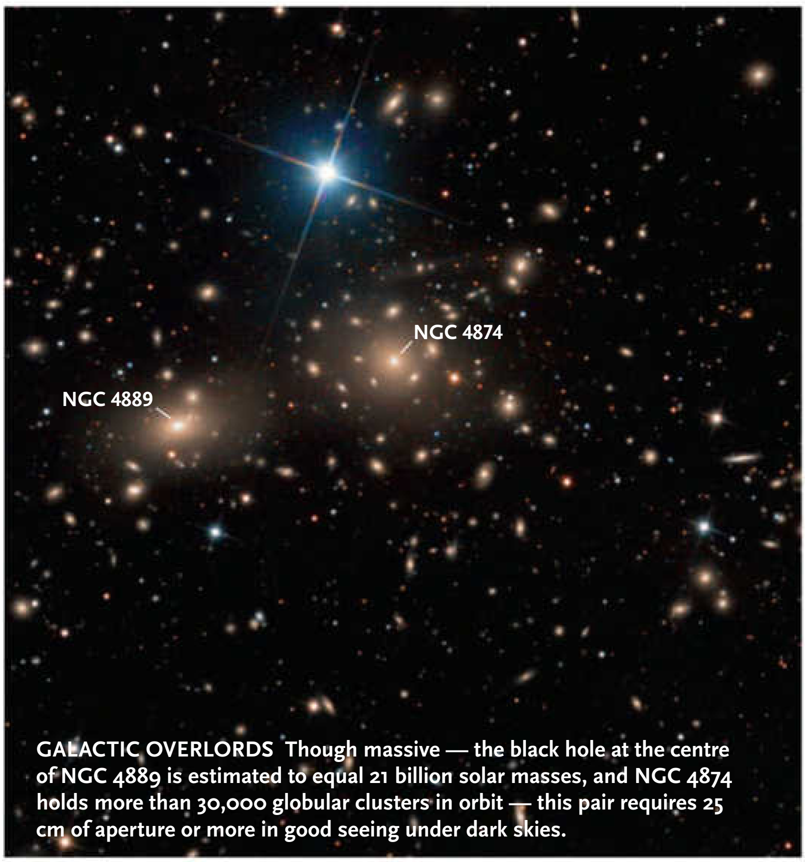
With their (mostly) high surface brightness, quite a few giant ellipticals and cD galaxies are well within the range of the typical backyard observer. To start your journey, check the core regions of large galaxy groups for potential targets. With a little research and planning, you'll be ready to conquer even the most monstrous of these giant galaxies. ✦

A MIGHTY JET A jet of gas and dust (arrowed), visible here to the northwest of M87, blasts from the black hole at the centre of the galaxy at nearly the speed of light; it extends at least 5,000 light-years from its source.



NEAR COLLISION Ellipticals NGC 4782 and NGC 4783 started life as separate objects, but a high-speed near-collision left behind a loosely bound interacting system that resembles a dumbbell through the eyepiece.

RICHARD JAKIEL (2)



GALACTIC OVERLORDS Though massive — the black hole at the centre of NGC 4889 is estimated to equal 21 billion solar masses, and NGC 4874 holds more than 30,000 globular clusters in orbit — this pair requires 25 cm of aperture or more in good seeing under dark skies.

BOB FRANKE

The definitive barred spiral

The only thing as amazing as a supermassive black hole is the galaxy that surrounds it.

"Of all the barred spirals I've looked at, NGC 1365 is the only one that looked like one. It's on the edge of a dense galaxy cluster, which is full of bright galaxies." — September 18, 1993, 50-cm f/5, 182×

Although I've seen other galaxies that look like barred spirals since I wrote this observing note in 1993, NGC 1365 is still my favourite. The classic symmetry of its spiral arms is simply irresistible. It also has a remarkable supermassive black hole in its centre that mangles both spacetime and the imagination.

Images such as the European Southern Observatory photo shown here prove 1365's visual appeal, and the science of how the black hole might interact with the rest of the galaxy is a fascinating topic all its own.

NGC 1365's gracefully curved and pleasingly symmetrical spiral arms, attached to the ends of a short central bar, are probably familiar because it's so photogenic. It's the very definition of a barred spiral galaxy — in fact, if you Google 'barred spiral galaxy,' the first entry is an image of 1365.

ESO / IDA / DANISH 1.5-M / R. GENDLER, J-E. OVALDSEN, C. THÖNE, AND C. FERON

NGC 1365 is a member of the Abell Galaxy Cluster S373, but it easily stands out as the most visually interesting galaxy of the group. At 56 million light-years away, it's apparently on the near side of the cluster, which averages 62 million light-years distant. At approximately 200,000 light-years across, 1365 is twice the size of our Milky Way. Incredibly, in 2013 its two million-solar-mass central black hole was found to be spinning relativistically by the Nuclear Spectroscopic Telescope Array (NuSTAR) and the European Space Agency's XMM-Newton X-ray satellites (more about this amazing discovery later).

The spiral arms

I love seeing spiral arms in unimaginably distant galaxies, and in my book 1365 has two of the best. They're the most distinctive part of 1365, and the brightest segments of the arms appear as rather straight brackets on either side of the core.

My series of sketches show the arms at various lengths depending on the conditions and size of the scope. I made 2014 (20-cm) and 2008 (71-cm) observations in nearly ideal conditions, but my most detailed view to date was in 2013 through a 122-cm f/4 telescope. The view was impressive, easily offering detail that was beyond what I've seen through my own scopes and tantalising with the promise of more. The long, gracefully curved spiral arms hinted at considerable internal detail with two bright knots in the southern arm, which also showed slightly more of its fainter curved extensions than the northern arm.

These knots don't align with any H II regions of ionised atomic hydrogen, but rather appear to be star clouds. Also note that the base of each spiral arm extends slightly beyond each end of the bar.

I should mention that my 2013 sketch was made immediately after coming down the ladder from the eyepiece of the 122-cm scope, and although it was a quick-look impression on a sub-par night, this observation sparked an acute case of aperture fever.

How could it not? Now I can't help but imagine seeing each arm curving all the way around in bits and tufts, flanking its counterpart.

The central bar

My observing notes consistently state that 1365's central bar is fainter than the spiral arms and is much fainter than the core. Interestingly, murky sky conditions can mask the bar and produce a view that looks like the spiral arms aren't attached to the core.

Usually, though, the bar appears as a rather broad and evenly illuminated connection to the core. More precisely, the bar is in two sections, east and west. Although visually faint — I have yet to detect any detail within the bar itself — recent findings suggest gas and dust from the spiral arms is being funneled through the bar toward the core, forming new stars along the way. This may also feed the central black hole and could be part of the process that made it supermassive.

Finally, there's a faint foreground star tucked in near where the northern spiral arm connects with the central bar, and I've mistaken it for a supernova more than once. There's an even-fainter star right at the point where the bar really does connect with the spiral arm, but it took the 122-cm scope to see it.

The core

"Dim but distinct — the definitive barred spiral. The arms are more distinct than the bar, with the nucleus the brightest of all." September 21, 1998, 50-cm f/5, 282×

". . . (Note the split core!)" November 2, 2013, 122-cm f/4, 375×, 21.28 SQM

Aside from the spectacularly curved spiral arms, the egg-shaped core was obviously split by a dark lane when seen through the 122-cm scope.

Nonetheless, the core appears oblong and at somewhat of an angle to the brightest, straighter portions of the spiral arms. But as more of the arms become visible the more obvious it is that the major axis of the core lines up with the overall shape of 1365.

This is the brightest part of the galaxy, and inside lives the relativistically spinning two million-solar-mass supermassive black hole I mentioned earlier — whirling at 84% the speed of light.

...Wait — what? 1365's supermassive black hole is spinning at 84% the speed of light?

Apparently so. Think about that for a moment.

It can't be seen visually, of course, but just knowing it's there — and trying to imagine the relativistic environment around it — is fascinating in the most delightfully mind-boggling way.

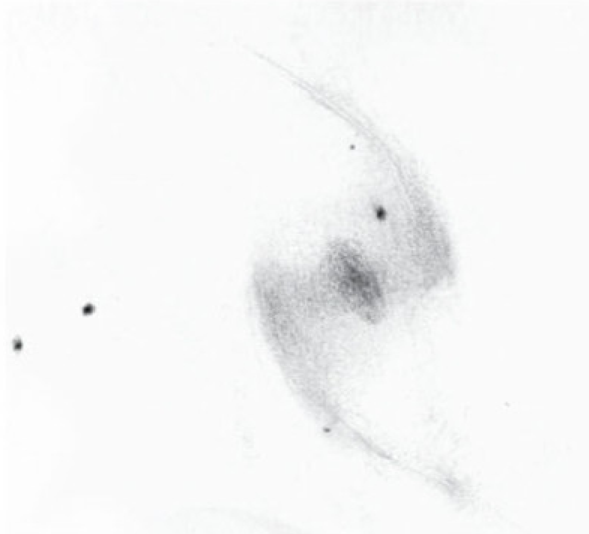
Aside from the outrageously twisted spacetime this implies, it also suggests the black hole has grown in a fairly orderly manner, because random growth would tend to slow its spin. Perhaps it's spinning so fast because of how the bar funnels gas and dust toward the core from the spiral arms, but that's unclear just yet. Still, it's tempting to speculate that 1365 is shaped the way it is because of how it feeds the black hole.

However, the fact that you can see the core that surrounds this beast with your own telescope — not to mention the bar and spiral arms that might be fueling it — is nearly as amazing as a relativistically spinning supermassive black hole existing in the same universe as we do.

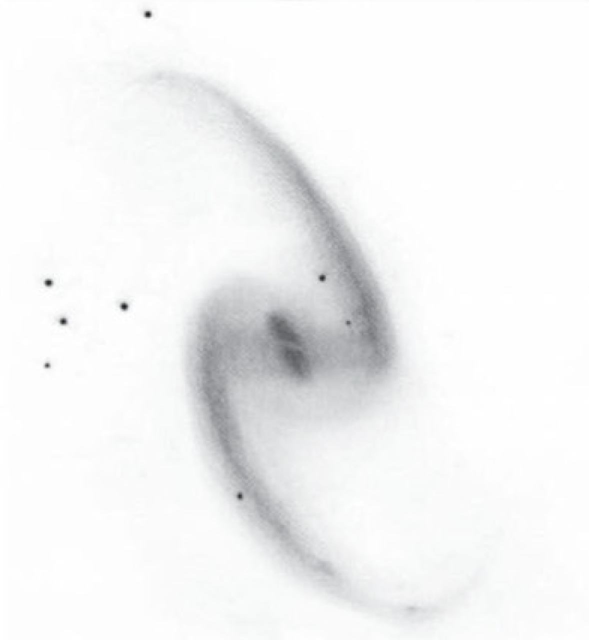
Keep this in mind the next time you observe 1365, and I guarantee it will look more interesting.

Can you imagine? ✦

ALL SKETCHES BY THE AUTHOR



"Wow, this is my best view of this terrific galaxy *ever*. The spiral arms get very long when I gently rock the scope back and forth, plus there's some detail in the arms as well." September 28, 2008, 71-cm f/4, 253× and 408×, 21.95 SQM



Composite drawing of NGC 1365 made by combining the author's sketches from his 50-cm and 71-cm telescopes and those made with a 122-cm.

Nikon's D810A full-frame DSLR is the company's first camera designed specifically for astrophotography. Its 36-megapixel sensor includes a modified long-wavelength filter that passes approximately 4 times as much hydrogen-alpha light as Nikon's other DSLR cameras.

ALL PHOTOS BY THE AUTHOR

The Nikon D810A DSLR camera

Nikon's Astro Camera

A giant in the photography industry makes its first foray into the astronomy market.

Can I get a hallelujah! Nikon has finally come out with a true astrophotography camera that isn't plagued by the quirks of past Nikon DSLRs when used for astro-imaging.

The D810A was announced in February of 2015, almost ten years after Canon announced its 20Da, the first dedicated astrophotography DSLR camera. It took Nikon quite a while, but they've pulled no punches with a camera that the company claims has "the best image quality in the history of Nikon digital SLR cameras".

Nightscape photographers will love the camera's high-ISO performance, built-in intervalometer, time-lapse functions, electronic front curtain shutter, and 'virtual horizon' settings. Deep sky imagers will be impressed with the camera's low noise, hydrogen-alpha (Hα) sensitivity and excellent dynamic range.

But be prepared — this is a complicated camera. The manual alone is 501 pages long, and the camera has 27 buttons, three dials and one multi-function selector. There are six main menus with 140 sub-menus, many of which also have multiple selections.

Specifications

The D810A is constructed around a full-frame 'FX format' 36.3-megapixel, 7360 × 4912-pixel CMOS array with 4.8-micron-square pixels. It records uncompressed 14-bit files in Nikon's proprietary NEF format that are about 75 megabytes when recorded, and 207 MB when opened in image-processing software and converted to 16-bit depth.

The high image quality of the D810A can be attributed to the excellent low-noise performance of its sensor, and its modified long-wavelength filter that passes four times more hydrogen-alpha light than a regular D810. This is great for recording those beautiful red emission nebulae.

The camera's ISO settings range

WHAT WE LIKE

- High-resolution, full-frame sensor with good Hα sensitivity
- Electronic front-curtain shutter
- Built-in intervalometer
- M* mode long-exposure settings

WHAT WE DON'T LIKE

- Non-articulated LCD screen
- Full-frame sensor's optical requirements

from 200 to 12,800, and Nikon's optical low-pass anti-aliasing blurring filter has been completely removed. The black point in raw images is slightly clipped, though this shouldn't affect your results whether you intend to use calibration frames or not.

Like most DSLRs today, the camera includes a Live View (Lv) function to help framing and focusing. The feed can be viewed on the camera's LCD screen at 1:1 pixel resolution and can be enlarged up to 23×.

The D810A connects to your computer via a USB 3.0 interface and can also accept Nikon's proprietary 10-Pin shutter release cables. It also includes a special M* exposure mode to access advanced shutter speeds of 4, 5, 8, 10, 15, 20, 30, 60, 120, 180, 240, 300, 600 and 900 seconds, as well as a Bulb setting for even longer exposures.

The electronic front-curtain shutter (d5 in custom settings) eliminates vibrations from mirror slap and the mechanical shutter opening. It's available only in Mirror Lock Up mode (Mup) and must be used with M or M* exposure mode. You can also program an exposure delay of 1, 2 or 3 seconds to ensure vibration-free images.

One great thing about this and other Nikon DSLR cameras is that they continue to use the standard Nikon F mounting bayonet in use since 1959, enabling photographers to use older, manual-focus lenses. I used my old Nikkor AIS manual-focus lenses with the D810A.

Collecting photons

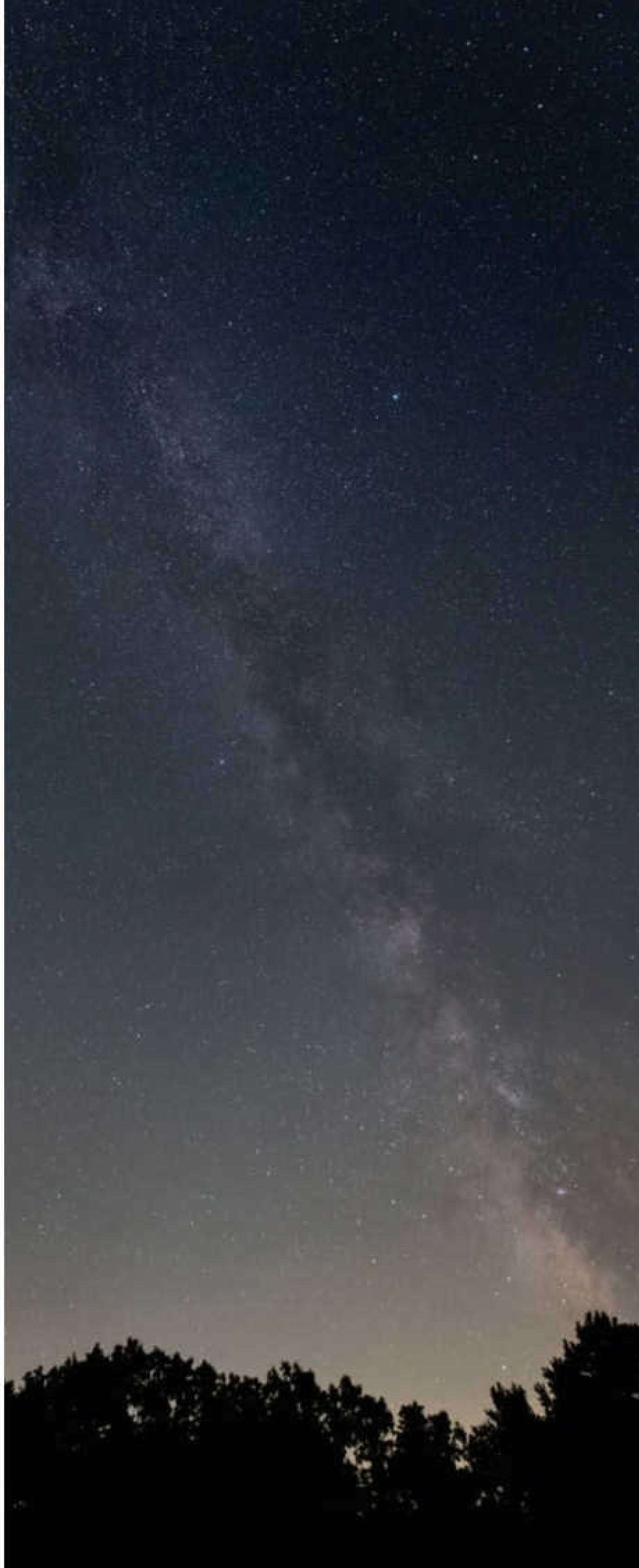
The first thing you'll need when shooting with the D810A is a high-capacity memory card or two, because they fill up quickly at 75 MB per raw image.

Battery life in the D810A was impressive. Its EN-EL15 battery lasted 5.16 hours in continuous use at 26°C. If you hope to use it throughout a long, cold winter night, plan on investing in a few extra batteries or on using an AC or DC power supply.

When shooting in the M* long-exposure mode, the D810A turns off all exposure indicators and lights. Though helpful, this can make it a bit tricky to see where you stand during an exposure.

The camera includes a helpful built-in intervalometer. This feature allows you to program the length and number of exposures you'll take in a sequence without needing an external device, as is usually required with other cameras. The secret to using it is to set the interval to the length of the

Menu and control settings in the D810A feature many options useful for astrophotography, including Interval timer shooting, Self-timer and High ISO NR (noise reduction).



This image displays the Milky Way spanning from Cepheus to Sagittarius in the large field of view of the AF-S Nikkor 14-24 mm f/2.8G ED lens on the Nikon D810A. The combination covers 104.25 × 81.2° at 14 mm. This single 15-second exposure at f/2.8, ISO 6400 shows the lens is well corrected even when used wide open at f/2.8 on full-frame sensors.

exposure *plus* the length of time you want in between exposures. And while you can't stop an exposure once it's started without powering off the camera, you can stop the intervalometer when it is between exposures by pressing the OK button.

The D810A offers long-exposure noise reduction. This is a common feature in which the camera takes an additional exposure of the same length as the previous image with the shutter closed, then subtracts that image from the last to remove dark current that adds electronic noise to an image. It's best to disable this function, as it doubles the time needed for exposures and really isn't necessary unless you are shooting at extremely high ambient temperatures. An alternative is to shoot these dark frames later and subtract them from your images manually with image-processing software.

One issue I had with the D810A was its lack of an articulated LCD screen, which would let you adjust it for convenient viewing when the camera is attached to your telescope. Though not a deal-breaker, it is a neck strainer, especially if you are using a refractor or catadioptric telescope pointed anywhere higher than about 15° above the horizon — in other words, for almost every astrophoto.

Like Nikon's other DSLR cameras, the D810A Lv mode image defaults to a correct brightness display, no matter what exposure the camera is set to. Users can enable an exposure simulation option in Lv mode in which the brightness of the display changes as you change the exposure. Press the OK button on the back of the camera while in Lv mode to enable this feature.

While shooting, be sure to save RAW images in 14-bit NEF lossless file format. The camera offers many other options such as a RAW Small format with one quarter the pixel count. This may seem attractive but should be avoided as it is not a true RAW file, and it is not actual pixel binning like that done in an astronomical CCD camera — this setting simply down-samples your image after the fact, rather than grouping pixels to make them act as a larger, more light-sensitive pixel unit.

Unlike some other DSLR models with Lv mode, the D810A isn't useful for high-resolution planetary imaging, because the Lv mode video stream is heavily compressed.

Left: **This enlargement shows hot pixels and colour noise from a 30-minute exposure at ISO 200 at 18°C ambient temperature.** ***Right:*** **The noise and splotches are completely removed with the special astro noise-reduction function in** ***Nikon NX-D v1.2.1*** **image-processing software.**

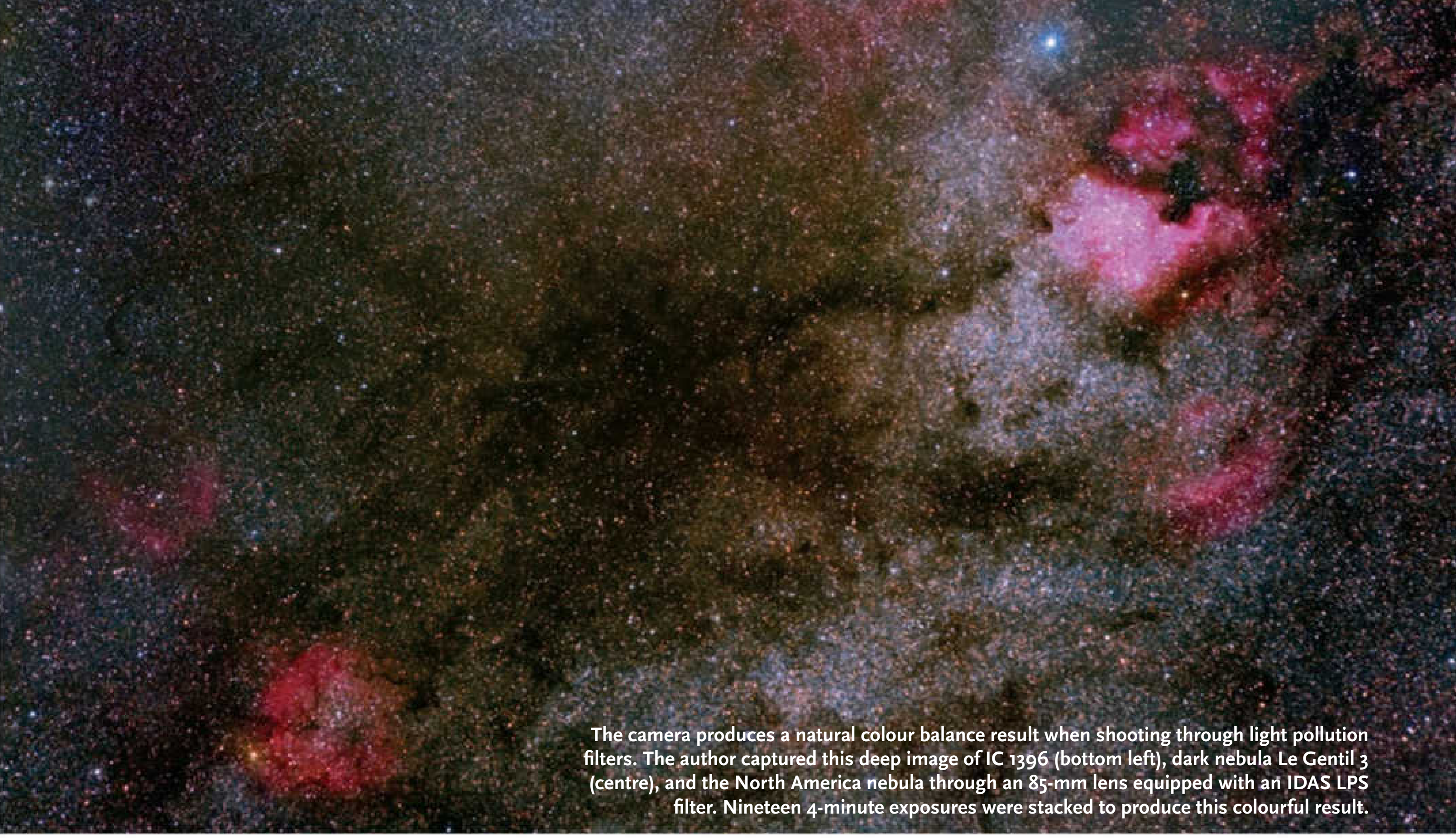
The D810A reveals its great colour performance on nebulae in this roughly 1½-hour photo of the Veil Nebula in Cygnus. The author captured the shot through an Astro-Physics 130EDFGT refractor working at f/4.7, and the individual images were aligned and stacked using ***ImagesPlus.***

Colour balance

Nikon states that the D810A is not recommended for general daylight photography. But in practice, the camera produces very good colour for normal daytime subjects, such as family snapshots.

Like most DSLRs, the camera's automatic white-balance settings produce inconsistent results with astronomical subjects. Choose 'Direct Sunlight' or, better yet, program your own custom white-balance settings to get the best results when shooting nighttime targets.

Once you start shooting with the Nikon D810A, the camera's extended Hα sensitivity immediately becomes apparent. Even short exposures of 15 seconds or so revealed red nebulous regions with untracked shots using the AF-S Nikkor 14-24mm f/2.8G ED lens supplied with our test camera for this review.



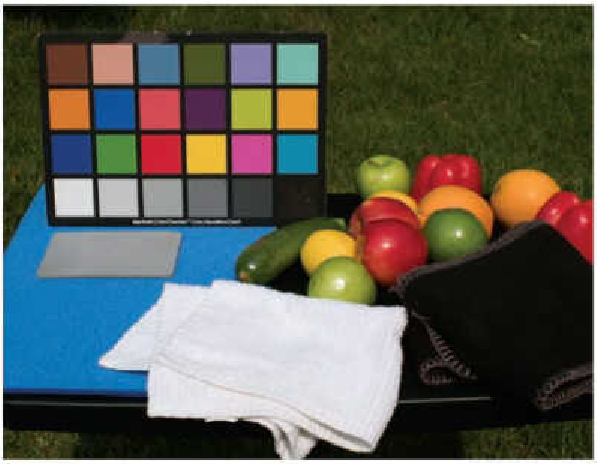
The camera produces a natural colour balance result when shooting through light pollution filters. The author captured this deep image of IC 1396 (bottom left), dark nebula Le Gentil 3 (centre), and the North America nebula through an 85-mm lens equipped with an IDAS LPS filter. Nineteen 4-minute exposures were stacked to produce this colourful result.

Nightscapes and time-lapse imaging

As mentioned earlier, the D810A has a number of features that are extremely useful for astrophotographers, particularly those who specialise in 'nightscape' photography. In addition to the built-in intervalometer, the camera includes an electronic 'virtual horizon' feature that helps you quickly level your camera and the subject in the picture frame. The intervalometer allows for fixed-tripod star trails and time-lapse sequences, as well as multiple individual shots.

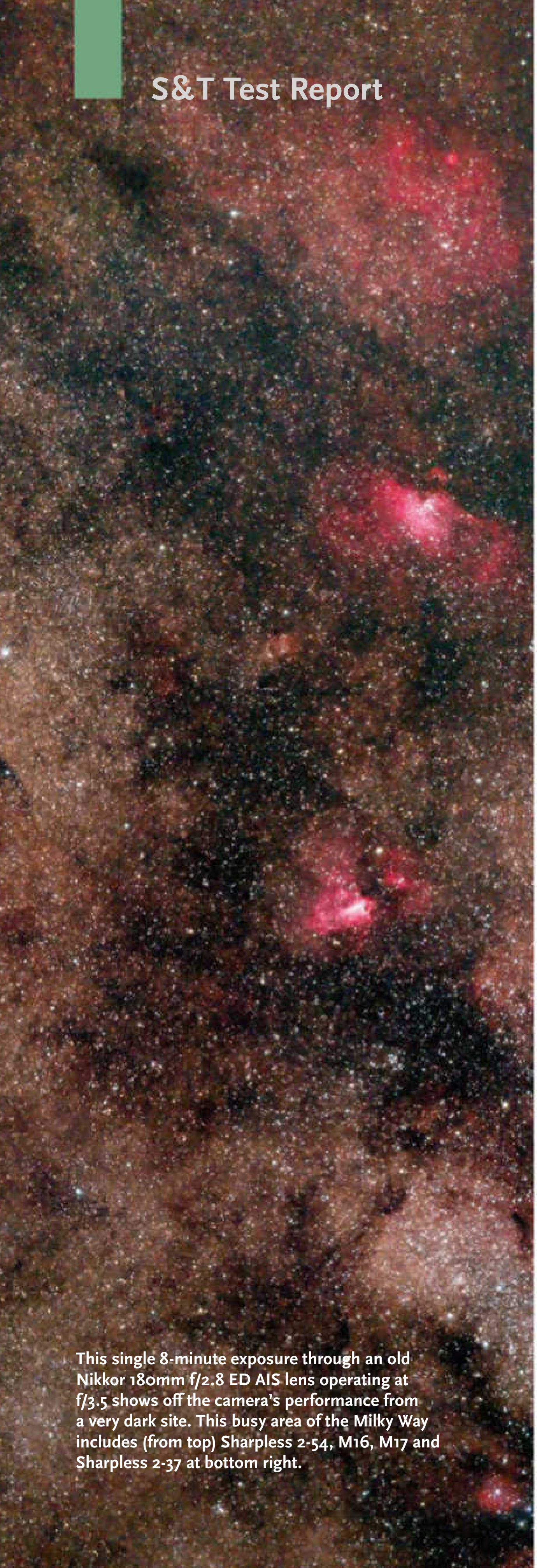
Using the continuous high (CH) or continuous low (CL) modes, you can shoot an unlimited number of images continuously with a shutter speed of 4 seconds or longer, at least until you fill the memory card or exhaust the battery. Instead of a 999-frame limit found in most DSLRs, the D810A can record up to 9,999 frames using the interval timer function, permitting you to shoot sequences you can later assemble into time-lapse movies.

The time-lapse feature is independent of the intervalometer and creates compressed movies. It includes a useful smoothing function that attempts to adjust the exposure variations between frames that can result in brightness flickering. Unfortunately, the feature doesn't save the individual image frames. Serious time-lapse photographers should stick with the intervalometer function and save RAW files for more control in processing and assembly of the final movie.



Above right: **Daylight performance with the D810A is very good despite Nikon's disclaimer.**

Right: **The D810A full-frame sensor will reveal problems that aren't as apparent in cameras with smaller sensors. Vignetting and mirror box shadowing are exaggerated in processing to show these effects in this image shot with an Astro-Physics 130EDFGT triplet apochromatic refractor at f/4.7 with AP's original 0.75x focal reducer. Flat field calibration frames can correct these illumination issues.**



This single 8-minute exposure through an old Nikkor 180mm f/2.8 ED AIS lens operating at f/3.5 shows off the camera's performance from a very dark site. This busy area of the Milky Way includes (from top) Sharpless 2-54, M16, M17 and Sharpless 2-37 at bottom right.

Through a telescope

As suggested by my tests with camera lenses, the D810A is excellent for deep sky astrophotography through a telescope. The camera has extremely low thermal signal compared to other DSLRs. I shot a single 30-minute exposure at ISO 200 with an ambient air temperature of 18°C and was amazed at the large dynamic range and how well controlled the noise was. The resulting image displayed no banding or pattern noise.

Software compatibility

The camera comes with *Nikon Capture NX-D* 1.2.1 image-processing software, which includes a good noise-reduction feature that removes hot pixels and colour noise blotches from your long exposures. While this program has some excellent camera-specific features that reduce vignetting and some chromatic aberration in camera lenses in its extensive database, it's written for conventional photography and doesn't include other astronomy-specific features such as alignment or image stacking.

Nikon's optional *Camera Control Pro 2* software will run the D810A from your PC or Mac, but keep in mind the software will not interface with your telescope mount, and you have to pay extra for it.

For serious astrophotography, consider purchasing a third-party control program that includes many helpful features to get the most out of your time with the D810A. The proprietors of *BackyardNIKON* (**otelescope.com**) and *ImagesPlus* (**mlunsold.com**) kindly supplied me with working beta versions of their camera-control programs to run the D810A during my long-exposure deep sky imaging sessions. Both programs worked well. I calibrated, aligned, stacked and processed all of the deep-sky photos accompanying this review using *ImagesPlus*.

Summing it up

It is great to see Nikon enter the astrophotography market with an excellent, well-executed, high-end, professional-model, full-frame DSLR camera body.

Those shooting from very dark sites will really appreciate the low read noise of the D810A. Its low thermal signal combined with the astro noise reduction feature in the Nikon software work so well that you'll hardly need to shoot dark frames anymore!

This sensor's large format and high resolution can produce outstanding results if you have an optical system capable of taking advantage of it — scopes paired with the D810A should be top of the line and able to produce pinpoint stellar images across a 24×36-mm field. This is an instance of 'be careful what you wish for,' because the D810A can reveal optical problems you didn't know you had and cause additional expenses you might not have expected, both in terms of memory and processing requirements, as well as the need for top-notch, well-corrected optics.

The bottom line is that the D810A is an outstanding camera for long-exposure deep sky imaging, and it is undoubtedly going to be the go-to camera for nightscape and time-lapse photography.

It's nice to see Nikon finally focus on astrophotography and give Canon some real competition, which can only be good for DSLR imagers everywhere. ✦

Jerry Lodriguss specialises in astrophotography with DSLR cameras. See his latest work at ***www.astropix.com****.*

A finely finished reflector

A few finishing flourishes often separate a good scope from a great one.

Wow — he thought of everything. That's what went through my mind as I watched telescope maker Miles Waite assemble his 35.5-cm Dobsonian reflector. When he was done, I stood impressed with the scope's overall appearance and the particularly fine craftsmanship in evidence. But it's all the little thoughtful touches and attention to detail that makes this scope extra special.

Miles is typical of many telescope makers I've met over the years — he wanted an instrument customised to his specific observing needs that also appealed to his aesthetics. But the road to completion for this scope was perhaps a little longer and more winding than most. Having successfully made a 24-cm mirror before, he was ready to try his hand at something more ambitious.

"I would say that in this case, the mirror chose me," Miles says. "A friend owned a commercial fishing boat and had a couple of surplus 35.5-cm diameter porthole windows he was removing... aperture fever struck and I immediately had visions of making a big telescope mirror."

One thing about working on a telescope mirror is that it gives you lots of time to think, and Miles used that time to work out the details of his dream scope. Eventually the planning and construction got ahead of the mirror's progress.

"Most of the scope's structure was nearing completion, and my mirror wasn't finished yet," he recounts. "So, I decided to purchase a primary with the intention of swapping it for my own optic when it was done."

Telescope maker Miles Waite designed and built this superb, portable 35.5-cm f/4.7 truss-tube Dobsonian.

GARY SERONIK

The scope pictured here is the result. It's a lightweight, compact instrument with a f/4.7 focal ratio that places the focuser at eye level when the scope is aimed at the zenith. The telescope is made largely from aluminium stock. As Miles says, "One of the biggest challenges was bolting everything together accurately and securely; the only welding I did was a bit of brazing on the spider secondary holder bracket."

So what about those thoughtful touches I mentioned earlier? There are several, but let me highlight just a few that illustrate the care Miles put into the design.

First, the Achilles heel of most open-frame Dobs is the truss system that joins the front of the scope to the rear. Many are fiddly, and some invite potential

disaster with poles and hardware precariously attached until the assembly is completed. All six truss members in Miles's scope are joined together as a single unit that unfolds and attaches to the rest of the scope with captive bolts — there's nothing to lose in the dark or fall on the primary mirror. (But there's a mirror cover in place, just to be extra sure!)

I also like the nifty way the front sections of the side bearings fold in for a compact configuration that makes transporting the scope easier. These 'ears' swing into position and are locked in place by a pair of ordinary cabinet latches.

The scope also uses digital setting circles, but you might not notice them at first glance. Miles has done a superb job of routing the various wires that connect the encoders to the display unit so they're largely out of sight. The holder for the display is also a very nice touch — it's at a convenient height and location for easy access while using the scope.

A telescope is often more than the sum of its parts, and that's the case here too. Looking at the dozens of components that went into making this scope, I couldn't help but be impressed by the level of detail and care that went into every single piece. I shudder to think of the hours it must have taken to fabricate and finish them all. But the effort paid off. The resulting telescope has the look of something that emerged from a high-tech manufacturing facility, rather than an amateur's garage. "At star parties I've been asked what brand this scope is," Miles says. "People have a hard time believing that I actually made it!"

The scope breaks down into three main parts for transport: the secondary mirror cage, primary mirror assembly and truss unit.

GARY SERONIK

As Miles summarises, "The satisfaction from working with my hands, problem solving, and the finished product made it all worthwhile." One day, he might even get around to finishing that porthole mirror!

If you wish to learn more about the scope, you can contact Miles via e-mail at jmwaite@shaw.ca. ✦

Stardate South Island
February 5-8, 2016

The companion even to Stardate NI, to be held at Staveley.
treesandstars.com/stardate/

Astrofest 2016
March 12, 2016

Australia's largest free public astronomy event, held at Curtin Stadium on the Curtin University campus in Bentley, Perth.
astronomywa.net.au

National Australian Convention of Amateur Astronomers
March 25-28, 2016

Held every second year, the NACAA is Australia's premier get together for amateur astronomers to discuss research projects and the latest technologies. In 2016 it will be hosted by the Sutherland Astronomical Society in Sydney.
nacaa.org.au

Royal Astronomical Society of NZ Conference
May 2016

Annual meeting of New Zealand's astronomers
hbastrosoc.org.nz/rasnz-conference-2016/

South Pacific Star Party
May 5-8, 2016

Annual star party hosted by the Astronomical Society of NSW
asnsw.com/spsp

Queensland Astrofest
August 2016

Lions Camp Duckadang, Linville, Qld

Long-running annual star party
www.qldastrofest.org.au

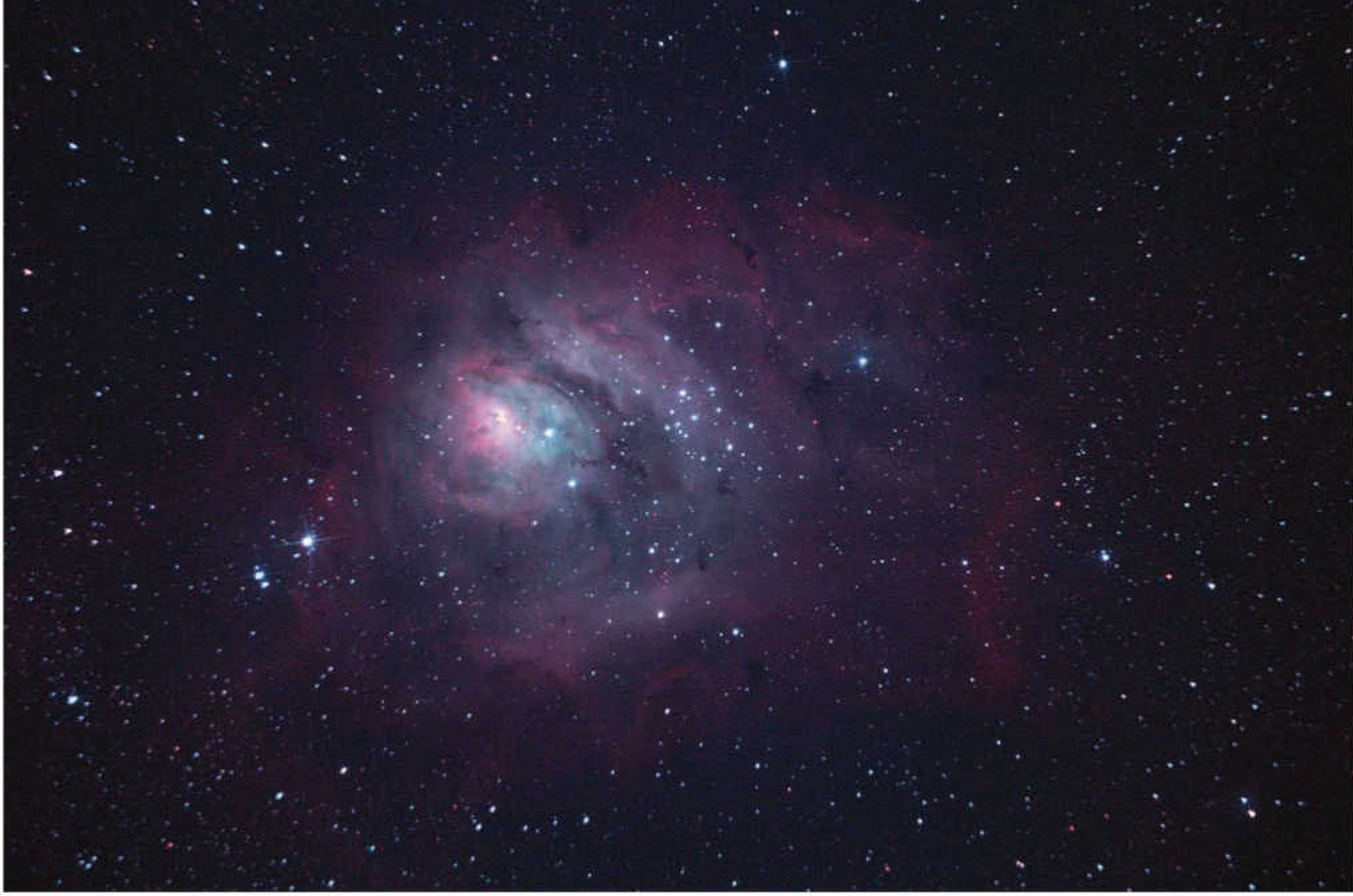
National Science Week
August 13-21

Various activities around the nation
www.scienceweek.net.au

WHAT'S UP? Do you have an event or activity coming up? Email us at editor@skyandtelescope.com.au.

Astrophotos from our readers

▲ **MEN IN THE MOON Teale Britstra**
The International Space Station crossed in front of the Moon on November 21, and Teale grabbed the opportunity to capture the moment. He used a Celestron CPC 800 SCT with 0.63x focal reducer and a Canon EOS 600D DSLR (1/1600th second, ISO 800).



▲ A DIP IN THE LAGOON
Frank Testa
The Lagoon Nebula is a huge star-forming region in Sagittarius. Frank used a non-guided SkyWatcher AZ-EQ6 mount, a SkyWatcher Black Diamond 20-cm reflector and Canon EOS 60D non-modified camera with a light pollution filter.

◀ PTOLEMY'S CLUSTER
Mike O'Day
Also known as Messier 7 and NGC 6475, Ptolemy's Cluster is about 980 light-years away and comprises around 80 stars. Mike used a SkyWatcher Quattro 25-cm f/4 Newtonian on a SkyWatcher AZ-EQ6 GT Mount, Orion auto-guider, Baader MPCC Mark III coma corrector and a Nikon D300 DSLR camera.

HOW TO SUBMIT YOUR IMAGES

Images should be sent electronically and in high-resolution (up to 10MB per email) to *contributions@skyandtelescope.com.au*. Please provide full details for each image, eg. date and time taken; telescope and/or lens; mount; imaging equipment type and model; filter (if used); exposure or integration time; and any software processing employed. If your image is published in this Gallery, you'll receive a 3-issue subscription or renewal to the magazine.

▲ **GHOSTLY VISITOR Peter Brackenridge** During some night-time photography in rural Western Australia, an owl paid Peter a visit. He used a Nikon D810A camera, Nikkor 14-24mm lens at 14mm, f/2.8, ISO 800, plus a brief burst of light from a torch to illuminate the owl.

▲ **ONE WITH THE LOT Jamie Pole** This image, taken at the recent Snake Valley Astro Camp, has it all – the Magellanic Clouds, a meteor and an auroral display. Jamie used a Canon EOS 6D with a Nikkor 14-28mm f/2.8 lens on a Novoflex adaptor for the 30-second exposure.

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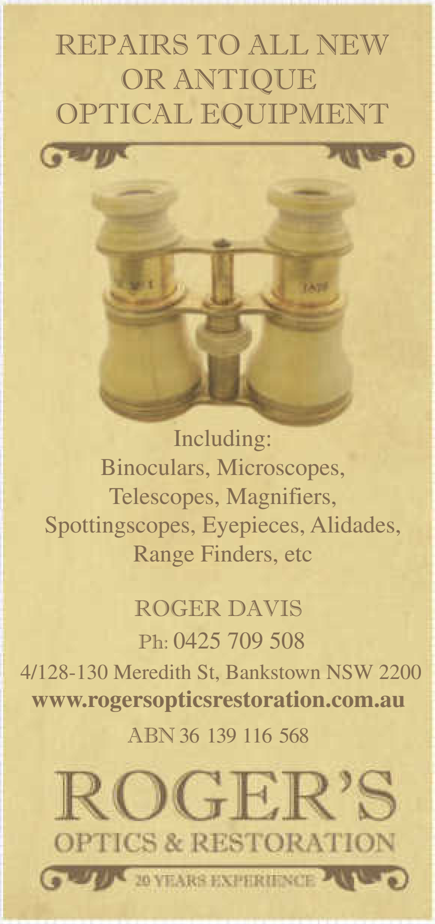

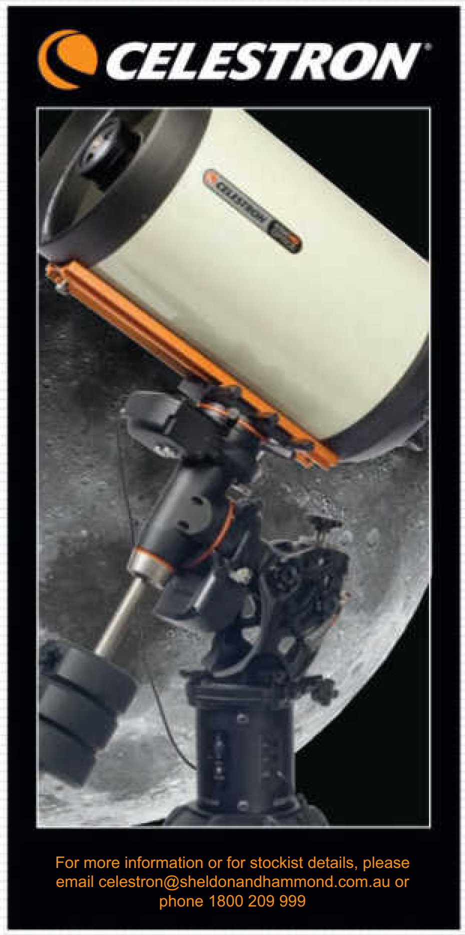

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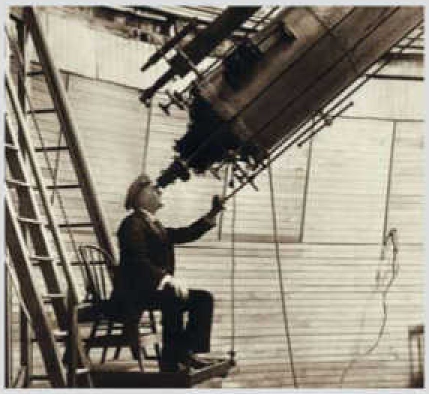

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Be amazed.

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Our societal fearfulness exacts a toll on astronomy.

In June 2005, an 11-year-old Boy Scout strayed onto the wrong track and was lost for four days. He scrupulously followed all the advice grown-ups had given him, and it nearly killed him. He stayed on the trail, which was good advice. But he'd also been told never to talk to strangers, so any time a rescue party came near, he hid in the bushes. Finally, common sense got the better of caution, and he revealed himself to a rescuer.

How attitudes have changed! When I was an 11-year-old, my parents let me go just about anywhere I wanted alone. Back then that was pretty much the norm, though a few parents were more cautious. But parents who were considered comically overprotective in the '50s and '60s might be judged reckless by today's standards.

It's not that the world has become more dangerous — if anything, the opposite is true. Crime rates in most categories are just about the same as or better than they were 50 years ago, and accident rates have dropped significantly. Yet in the past half century, we have become a deeply fearful society.

What does this have to do with astronomy? A great deal, unfortunately. Fear is a major driving force behind light pollution — in particular, behind those blinding 'security lights' that defile untold hectares of otherwise pristine rural land. And fear is one of the main reasons that it's so hard to find a good observing site near my city home. Almost every plot of public land within a 50-kilometre drive has a sign saying that access is prohibited from sunset to sunrise.

S&T: LEAH TISCIONE

When my parents were born, life was genuinely dangerous. Women often died in childbirth, infants died of measles, millions had just been killed in World War I, and far more would soon die in World War II. Even the richest family was vulnerable to infectious disease.

Only in my lifetime has the idea taken root that life can or should be lived completely free of risk. But that's an illusion. In pursuit of that goal, we confine ourselves to environments that we can rigidly control: the home and backyard, the car and the shopping mall. Thus we end up with the diseases of civilisation: obesity, arteriosclerosis and diabetes, which kill far more people than the dangers that we're hiding from.

Small wonder that people don't enjoy the marvels of nature — stars included. Small wonder that people want to make the outdoors just like the indoors, to pave it or plant it with well-manicured grass, to fence out all intruders, to light up every square metre so that night is turned to day. Small wonder that 90% of people live where skyglow obscures the Milky Way — and that many of the rest haven't seen the Milky Way either, because they're afraid to turn off their outside lights.

At a deeper level, I've had several people tell me that the stars scare them. Frankly, I can sympathise with that sentiment. The stars are utterly alien, completely and forever beyond our control. Awe and fear are intimately related. And there's nothing wrong with that. Fear is a perfectly healthy response — unless you run away from it. ✦